NEW CONCEPTS
IN
AGRICULTURAL EDUCATION

NEW CONCEPTS IN AGRICULTURAL EDUCATION IN INDIA

Edited by

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Dedicated to

Dr. D. C. Pavate

Chancellor, Punjab Agricultural University

Preface

This book is written primarily as a stimulus for the teacher and student of agriculture as well as for the politicians who are guiding the destiny of our people.

In the past, the field of agriculture has had the stigma of being one of the lesser professions, being made up mostly of frustrated students who had aspired for other fields such as medicine, law, engineering, but who could not gain admission because of poor economic circumstances or low academic record. This myth is no longer valid.

Today, agriculture has risen to a prominence almost second to none. Ten exclusive Agricultural Universities have been set up in India. Some of the most staggering discoveries have already been made in these institutions resulting in an almost unbelievable increase in food production. Our own University has become one of the pioneers in the field of research.

Foremost among the men who have steered the growth of these Institutes are Dr. S. Radhakrishnan, Dr. Frank Parker, Dr. P. N. Thapar and Dr. M. S. Randhawa. In our Institute, in the short space of five years, Dr. Thapar instilled a fiery enthusiasm into his well chosen staff so that it became the most outstanding Agricultural University in India. Now the University is again fortunate indeed to have at its helm, the eminent and dynamic Dr. M. S. Randhawa whose contributions in the field of agriculture and science are well known. The right leadership in every University is of utmost importance.

There is much to be done as yet and it shall require the genius and men of such calibre to continue providing the impetus for agricultural scientists to evolve newer and better methods of food production so that the foodgrain requirements of the population explosion can be met.

In order to achieve this goal, the students of teaching and research must be trained to first class levels. All mediocre colleges must forfeit their privileges of awarding agricultural degrees as they have neither the staff nor the equipment for teaching agriculture. The standards for admission must be raised.

In the summer of 1967, a seminar was arranged by the Punjab Agricultural University in which educationists and scientists from various Agricultural Universities and other Institutions in India were invited to participate and discuss the new concepts in agricultural education in the country. In this seminar, we have dealt with many of these problems, stressing the role of biological and physical sciences in our curricula; the importance of research; the projects underway at our University and other research institutes and the problems of the future.

Many of the papers in the teaching method portion or on agricultural administration contain personal thoughts of the speaker and do not necessarily mean a stamp of firm approval by the editor. The reader is left to decide for himself which are the best suggestions and which can be readily implemented for the uplift of our teaching standards.

The scope of teaching in Agricultural Universities is much wider than that envisaged in the traditional Universities in India or elsewhere. Education not only means a formal scientific training in a given profession but an entirely a new outlook on solving problems of the under-privileged rural people. It means a directed effort to train people, both young and old, in tackling the foreseen and unforeseen situations that emanate from a tradition ridden and custom oppressed society. The training desired to be given is such that a graduate from an Agricultural University must acquire the ability and confidence to be able to uplift the peasant, in body, mind and soul. Thus, education in Agricultural Universities has a different meaning, a different purpose, and altogether a different philosophy which pervades not only the sphere of a prospective graduate but also that of a semi-literate, diffident and humble peasant who might come for a short course in this high seat of learning.

Likewise the research to be conducted in Agricultural

Universities must be directed to solving problems of the farmers or other rural people who earn their subsistence, from the soil. Much is said about the basic or fundamental research as the only spring of knowledge for applied research. This controversy is futile. Has there ever been the start of a thinking process, or a discovery without there being a need or a desire or a compulsion for it ? True, in the process of that attainment many fundamental principles and laws have been laid down. But does that mean the original motivation of purpose in research should be made subservient, and must remain so under the brand of applied research, always ? An under-developed country, like India, can ill afford delays through such intellectual pursuits. On the contrary, India should follow the example of small industrious nations like Japan, Switzerland and Germany, where a handful of scientists have made great discoveries and interestingly enough in those fields which later on were exploited for the improvement of agriculture and industry.

The success of these teaching and research programmes is dependent not only upon the Universities but also upon the Central and State Governments. The latter must become keenly aware of the vast potentialities of the field of agriculture and must give due perspective, priority and above all, the required financial aid for these schemes.

To this end, we hope this book may serve some useful purpose for our country.

Some of the papers, included in this book were specially requested from the authors on individual merit or with the hope that a gap in the continuity of ideas might be filled suitably. I thank those authors and I am particularly grateful to Dr. E. C. Stakman for agreeing to my request at a short notice. I also thank all my colleagues who helped me in organising this seminar and the participants who put in hard work in writing and discussing their papers. I feel indebted indeed to my wife for her valuable assistance and encouragement in compiling this book.

Ludhiana, June 28, 1969 A. S. ATWAL

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M. S. RANDHAWA*
D.SC. (PB.)

The earliest universities in India were established by the Buddhists at Takshila, Nalanda and Vikramshila. They attracted students, from all parts of India as well as Central Asia and China, who came for study of Buddhism, metaphysics, and astrology.

During the Moslem rule education was mainly conducted in *maktabs* and *madrasahs* attached to mosques. Subjects taught were Arabic and Persian languages, mathematics, medicine and astrology.

The modern university as we know it in India is an importation from the West. Bologna and Paris which date back to twelfth century were the earliest universities in Europe. The curricula of these universities were based on Aristotle's *Ethics*, Ptolemy's *Almagesta*, and the *Topics* of Boethius. Bologna and Paris provided teachers to other universities in Europe which followed. Their great contribution to society, as Rashdall observes, was that 'they placed the administration of human affairs in the hands of educated men'. They produced theologians, lawyers and physicians who occupied positions of responsibility in Church and State. By the end of fifteenth century there were seventy universities all over Europe.

Modern science arose in the eighteenth century and the universities which so far relied on classical education in Latin and Greek incorporated science into their curricula. The Universities of Oxford and Cambridge had professional faculties in Theology, Law and Medicine. Apart from teaching these subjects, their emphasis was on character

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later on the other cities in India. Apart from defects of parrot-learning and reliance on note-books the universities were much too dependent on the government. As Eric Ashby observes, 'Anyone who studies the story of universities in India since 1857 cannot escape the conclusion that the system of higher education inherited at independence from the British Raj was dangerously weak in three ways : (i) During British rule we failed to set and maintain the quality of teaching and the standards of achievement essential to a university if its degree is to be freely acceptable in universities overseas. (ii) We failed to devise, and to persuade Indians to accept, a content of higher education suited to India's social and economic needs. (iii) We failed to establish patterns of academic government and relations between universities and the state, which would accord to universities that degree of autonomy without which they cannot serve society properly. The result was that on independence, the Indians inherited in their universities a massive invalid unable to respond to any simple treatment[1].'

In 1959 a remarkable development took place in Indian education. American ideas began to make impact on the thinking of Indian educationists. Moreover, needs of a developing economy dictated emphasis on agricultural education. The Second Joint Indo-American Team which was headed by me, in their report submitted in July 11, 1960, recommended the establishment of an Agricultural University in each State. It emphasized that in such universities there should be adherence to basic principles such as autonomous status, location of Agricultural, Veterinary, Animal Husbandry, Home Science, Technological and Science Colleges on the same campus, integration of teaching by offering courses in any of these institutions to provide a composite course, and integration of education, research and extension.

Since 1960, nine Agricultural Universities have come into existence in the States of Uttar Pradesh, Punjab, Andhra Pradesh, Madhya Pradesh, Mysore, Orissa, Rajasthan, Maharashtra and West Bengal. A few more are likely to come up during the Fourth Plan Period.

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[1] Eric Ashby-*Universities : British, Indian, African* ; p. 138.

hunting gear and his gun; or from the German aspirant asking shyly whether he may enter the professor's laboratory as a disciple. While Oxford and Cambridge slept, insulated by Anglicanism, from influences from abroad, the Scottish universities maintained a constant traffic of ideas, especially with the universities of Holland. This was one cause of their vitality. In philosophy, science, and medicine, they provided an austere but healthy diet; moreover they precipitated the reform of higher education in England."

In March 1835, Lord William Bentinck issued a resolution which asserted, 'the great object of the British Government ought to be the promotion of European literature and science among the natives of India; and that all the funds appropriated for the purpose of education would be best employed on English education alone'. In 1837 English superseded Persian as the official language of the law courts. The number of students in Calcutta University had grown from 280 to 800 in 1857 which was much larger than that of the London University. It had risen to 4,000 in 1882, and thus tropical luxuriant growth became a source of alarm to the British educationists.

The major defect in teaching in Indian Universities was that emphasis was on prescribed books rather than on subjects. As Eric Ashby observes, 'If in some respects the system was at fault, there were special features in the Indian environment to accentuate its defects and confirm the trend to shallow scholarship. With its broad spread and prescribea epitomes, the curriculum was inherently vulnerable to learning by rote; and as a result of centuries of learning by this method, the capacity and instinct of the Indian for memorisation was unusually strong. The traditional system of education had also endowed him with other intellectual qualities to hinder his progress in western scholarship; a reverence for authority which sapped his critical powers, and a speculative bias which weakened his ability to observe and appreciate facts, whether historical or scientific[1].'

Calcutta provided a model to Madras and Bombay and

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[1]Eric Ashby-*Universities: British, Indian, African*: A Study in the Ecology of Higher Education. Harvard University Press, Cambridge, pp. 67, 68.

training and they became nurseries for leadership in Church and State. Another ideal which motivated scholars in these universities was disinterested pursuit of learning. This led to many discoveries in basic sciences.

While Oxford and Cambridge were residential teaching universities a new type of university developed in London in 1836 which was merely an examining body. The University was governed by a Senate whose members were the nominees of the Privy Council. The university staff all of whom were administrators and clerks were paid by the Government. The examination and graduation fees were credited to the treasury who made up any deficit or raised any profit. From 1836, the year when it was founded, till 1900, the university did no teaching. The type of university transplanted in India in 1857 was based on the London model. It was an interesting experiment in social biology as it was for the first time universities were founded in non-Christian societies supplanting ancient indigenous centres of learning. While India accepted the London model, Japan in 1872 adopted the French model.

There was another type of university, the Scottish University which would have provided a better prototype for India. "The Scottish University in the nineteenth century was admirably adapted to its social environment", observes Eric Ashby. "Universities were open to all comers, with no entrance examination and very modest fees. Even if the parents were poor, it was the custom for the cleverest boy in the family to be sent to the university. So many of them were the sons of peasant-farmers that the terms were arranged to fit the agricultural year; boys left their farms after they had harvested the grain and they returned the following spring in time to cut the hay, or often even earlier to sow the grain. Study had to be sandwiched between the annual cycle of crops. They walked from their homes, a hundred miles perhaps, to the university, carrying a sack of oatmeal for food. They lodged in some cheap room in the city. Poverty protected them from temptations. When term was over they walked home in parties, some of them taking three or four days over the journey. Every village they passed through recognised them as scholars, and they could count on hospitality on the way. This is a world away from the Eton schoolboy arriving by coach at Cambridge with his

hunting gear and his gun; or from the German aspirant asking shyly whether he may enter the professor's laboratory as a disciple. While Oxford and Cambridge slept, insulated by Anglicanism, from influences from abroad, the Scottish universities maintained a constant traffic of ideas, especially with the universities of Holland. This was one cause of their vitality. In philosophy, science, and medicine, they provided an austere but healthy diet; moreover they precipitated the reform of higher education in England."

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The development patterns as also the functions and responsibilities delegated to these Universities, however, have varied from State to State and in some cases do not strictly conform to the central concept behind this institution building process as laid down in the Model Act for Agricultural Universities. Transfer of state-wise agricultural research, education and extension to the Agricultural Universities is the first requisite if the objectives of integration are to be achieved and these institutions are to make their contribution on the agricultural production of a State.

Relationship of Indian Agricultural Universities with the U.S. Land Grant Universities : The T.C.M., now A.I.D. Programme that started in India in 1956, was on a regional basis for agricultural education. The trend to one Agricultural University for each state took shape in 1960 and all AID support has been on a state basis since 1963. There are at present eight Agricultural Universities being assisted by the Agency for International Development through six U.S. Land Grant Institutions. These relationships are : Uttar Pradesh Agricultural University and the University of Illinois, Punjab Agricultural University and the Ohio State University, Andhra Pradesh Agricultural University and Kansas State University, University of Udaipur and the Ohio State University, Jawaharlal Nehru Krishi Vishwa Vidyalaya and the University of Illinois, Orissa University of Agriculture and Technology and the University of Missouri, Mysore University of Agricultural Sciences and the University of Tennessee, and Maharashtra Agricultural University and Pennsylvania State University. This university to university relationship is the bridge to scientific and cultural understanding between two great democracies.

Through USAID and these U.S. Universities, assistance has been given for training Indian Agricultural Universities' faculties. At present, there are 4,500 returned participants from AID programmes and over one-fourth have been related to agriculture, veterinary medicine, engineering and home science. Specialists from the U.S. Universities serving with Indian counterparts have been and are serving in teaching, research and extension education.

Other AID assistance has included limited amounts of equipment for teaching and research. All of these inputs—

participants, specialists and equipment, have aided the Indian Agricultural Universities to become real centres of new ideas and practices for India's agriculture.

Contribution of Agricultural Universities to Agricultural Production : The concept of integration of teaching, research and extension has already proved its worth through remarkable progress made in the field of agricultural education, research and extension by the new Agricultural Universities. There is perceptible improvement in the quality of education. There are more competent teachers, better equipped libraries, laboratories, and farms. The internal examination system is geared for continuous preparation on the part of both the students and the teachers.

These institutions are largely responsible for the development of the high-yielding varieties of wheat, maize, *bajra* and *jowar*. Unprecedented high crop yields have been recorded. Agronomic and plant protection practices to exploit maximum yield potentials have been developed and effectively extended to the farms. These institutions today are serving as fountain heads of new knowledge earned through purposeful, problem-solving research and have become main centres of dissemination of useful knowledge to farming community. Some of the best training for farmer is offered by the Agricultural Universities. There are numerous functional specialists who have gained confidence through experience in successfully applying scientific knowledge to the solution of practical problems.

The working conditions and incentives that they offer to the faculty and the students are providing opportunities for productive work, and are fostering team spirit and a healthy change in the outlook of all—the teachers and researchers, and the government administration. They are winning the confidence of the farmers. They have assumed leadership in science, education and extension. Their direct contribution to programmes like pedigree seed production, fertilizer use and National Crop Demonstrations is highly impressive. In this connection, the inter-institutional collaboration within the country and the international collaboration with the U.S. Universities needs special mention. Agricultural Universities are participating most effectively in the execution of the various coordinated programmes of

agricultural research initiated by the ICAR. Collaboration with U.S. Universities is aimed principally for advanced training of University personnel at institutions of repute in the U.S. and securing subject-matter specialists on long or short-term basis for helping to raise the standards of teaching and research at these institutions.

Besides improvement in quality, the new system of education has reduced the 'wastage' in higher education. This not only saves cost but provides training opportunities for more students.

It will not be out of place to quote some of the specific contributions made by the Agricultural Universities. The Punjab Agricultural University has made significant contributions in the cereal improvement programmes coordinated by the Indian Council of Agricultural Research in cooperation with the Rockefeller Foundation. In the field of extension, the Tungbhandra fertilizer use project executed by the University of Agricultural Sciences, Mysore, is an outstanding example of how new varieties of crops and agronomic practices can be speedily spread among the farming communities. The University took up the development of intensive farming in 10,000 acres of any irrigated land under the project. The project has been highly successful.

The Punjab State is known for its progressive farmers. An ambitious scheme of rural electrification has been taken up and private tube-wells at the rate of 20,000 per year are being energized. In the utilization of ground water, this is a major development. No doubt, the drought of 1965-66 has been the main stimulus in ground water utilization. The spread of high-yielding varieties of wheat developed at the University has been rapid and there is now adequate seed to cover entire irrigated areas in this State.

There is another role which the Agricultural Universities can play in the economic development of the country. This relates to advice to the Government of India and the State Governments.

It has to be admitted that in a number of cases policy-decisions are taken in the absence of adequate data and proper analysis. The Agricultural Universities have strong

Departments of Agricultural Economics which are in close touch with the farmers and their problems. As such they are in a position to advise the Ministry of Food and Agriculture of the Government of India and the Planning Commission on minimum prices for agricultural crops and on other policy-matters.

Planning of agricultural development in the States is also in need of improvement. Schemes are hastily prepared on the basis of working papers rather than on properly organised studies. The Agricultural Universities can carry on studies on problems relating to agriculture such as rural electrification, ground water, problems of water-logging and salinity, etc. The role of link roads and markets in agricultural production can be more precisely defined indicating where they are most needed.

Education : Needs and Virtues; Crimes and Misdemeanours

E. C. STAKMAN*
PH.D. (MINN.)

"Why is it so hard to find outstanding intellectual leaders in agriculture, when they are now so urgently needed ? A partial answer to this question, asked recently by an eminent student of public affairs, may be implicit in the statement of an eminent educator who said, 'American educators have done an outstanding job of selling schools to the American people, but they have done a very poor job of selling them education.'....The assigned title of my talk is 'The Training of Agricultural Scientists and Teachers'. There now is especially urgent need for agricultural scientists and teachers with deep and extensive scientific knowledge, mastery of skills and techniques, sound concepts, ethical standards, moral purpose, and real wisdom".

These statements are quoted from a speech that I made in 1956 at a meeting of the Association of Land-Grant Colleges and Universities in U.S.A. The need for leaders in agriculture seemed urgent then and seems even more urgent now, not only in the United States but in many other countries of the world. We must improve our genes or our education, or both, if we are to develop more and better leaders. It seems more feasible to try to improve our education than our genes. But how ?

"Do everything in education just the opposite from the way in which it has been done and you will do it right". Rousseau said essentially this some 200 years ago. Although somewhat hyperbolic, Rousseau's statement had much validity when he made it and still has some validity today.

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development of competence in the solution of basic social problems.

Throughout his post-Eden existence man has been confronted with three basic problems : human subsistence, often menaced by an unkind nature and by unwise men; human persistence, always menaced by accident, disease, and violence; and human relations, individual and "tribal", continually menaced by conflicting beliefs, interests, and ambitions, and by the greed and rapacity of man's own baser self.

Obviously, the most basic of these problems is that of human subsistence, because without subsistence there would be no human existence and consequently no human problems. The intent of this statement is not facetious; it is serious and is all the more seriously intended because there is a tendency in affluent and industrialized societies to ignore, depreciate, or scorn the problems of food production. It almost takes widespread famine to create widespread concern about food supplies and what it takes to provide them. Then a few verbally inventive people devise popular slogans, and, by repetitive propagation, most of the literate population become "experts", with easy opinions about food problems and their solution.

Fortunately there now is widespread concern about present and future food supplies in many countries and about future supplies in the entire world. And, even more fortunately, many individuals and agencies are seriously studying population trends in relation to trends in food production. A realistic appraisal of the results indicates not only the need for intelligent concern about the present population-food situation but also the need for intelligent and concerted action to prevent it from becoming worse.

Experts generally agree that half of the world's people are poorly nourished because of deficiency in quantity or quality of their food. There are estimates that half of the world's pre-school-age children are retarded physically or mentally, or both, because of nutrient deficiencies and that the death rate among them is 60 times higher than among those in well-nourished countries.

The food situation certainly is bad in many countries

My own experience with education provoked me once to remark that I contemplated writing a book entitled, "Educational crimes that I have witnessed". One result was an invitation to write this present paper under that title; however, justice would have impelled me to write also a larger book entitled, "Educational crimes that I myself have committed". Any indictment of education that may appear in the present paper, therefore, involves some self-incrimination. So I write what I write on the theory that it takes a criminal to catch a criminal. I am not a specialist in the history, science, or philosophy of education; nevertheless, even a non-specialist may be bold enough, or foolish enough, to express some opinions about education after having devoted himself to various kinds of educational efforts for more than sixty years.

Quoting from myself, "The general aim of education through the ages has been to prepare each generation for its physical and social environment ; to teach the young how to make a living and how to live in organized society. But environments change : civilized man is continually trying to alter and improve his physical environment, and some men are continually trying to change their social environment. Nature is dynamic and most societies are dynamic; hence education must be dynamic also if it is to perform its essential function. In most societies, however, there is a conflict between pressure for change and resistance to the pressure, between aggressive radicalism and defensive conservatism. As organized education is a social activity of some sort, its basic concepts, specific objectives, and general procedures vary with the varying social attitudes and objectives at different times and in different places".

One of the important variables in time and place has been the principle underlying the relations between the individual to be educated and the society that educates him. At one extreme there was the Spartan-type education for service to the State; at the other extreme, the education of the individual toward complete freedom of thought and action, as advocated by extremists in the Age of Enlightenment. Even today there is a widespread attitude on the part of some students that their only social obligation is to defy and disrupt the society that educates and protects them. But more about that later. One educational objective of most modern societies is the

death in 1834, and it is not restricted entirely to underdeveloped countries. Naturally enough, some pessimists assert that a considerable number of human beings always will suffer hunger and face the threat of famine. And some are fatalistic enough to predict that mankind will enventually starve to death. But need we be as pessimistic today as Malthus was a century and a half ago ? Malthus died some 20 years before the scientific revolution began; we are living in the age of modern science and have its tremendous potential at our command.

Man has become the potential master of his own fate in his struggle for subsistence.Thanks to science and technology, he has the means to restrict his numbers simply and humanely and to increase his food supplies quickly and substantially. But to become the actual master of his fate he must have the will and wisdom to utilize fully his present means and the wit to devise better ones for the future.

"A wise world will not starve to death; a stupid one might". Will wisdom dominate stupidity ? Man's own worst enemies in his struggle for a decent existence are ignorance, apathy, venality, and inhumanity; his best allies are knowledge, ambition, integrity, and humanity.

If the allies are to prevail over the enemies, there must be vast improvement in education; in large areas of the world it must become more functional. In all education two questions are always before us : (a) what are our educational aims and objectives; (b) what are the best methods for attaining them ? Every good teacher and every good educational institution should reflect critically and frequently on the aims, methods, and results of their educational efforts, with a view to continual improvement. It is important always to maintain an experimental attitude, because systems of education tend to become conservatively traditional and authoritarian, since many of them are based on preconceptions which tend to become self perpetuating. This tendency is accentuated by overemphasis on methods of instruction and underemphasis on methods of learning, on overemphasis on what is to be taught and underemphasis on the individuals who are being taught.

Teachers tend to become too unimaginative, too

now; and it is becoming progressively worse in some regions because populations have been increasing faster than food supplies, notably in Latin America, Africa, and the Far East. There is trouble ahead unless the efficiency of food production is increased and the efficiency of human reproduction is decreased. Many countries, already hungry, either must produce more food or fewer people, or both; otherwise millions of those yet unborn will be foredoomed to even worse hunger, poverty, and deprivation than those now living.

Eventually every country must adjust its population to its means of subsistence; it must produce enough food for its people or develop the purchasing power to buy it—provided enough food is available for purchase. But will enough always be available ? Some thoughtful people say that it will not, unless the rate of population increase can be reduced rapidly and drastically or food production can be increased quickly and substantially.

If present food-population trends continue, the world food situation will be critical and may be catastrophic within two decades, according to many competent students of the problem. Among neo-Malthusians there appears to be a growing conviction that Malthus probably was more right than wrong.

Quoting a dictionary, "Malthus held that population tends to multiply faster than its means of subsistence can be made to do, and that when this occurs the lower or weaker classes must suffer from lack of food; that, unless an increase of population be checked by prudential restraint, poverty is inevitable; and that the multiplying of the population will be checked by poverty, vice, or some other cause of suffering". Another dictionary says : "....that population tends to increase at a faster rate than its means of subsistence and that unless it is checked by moral restraint or by disease, famine, war or other disaster widespread poverty and degradation inevitably results".

Certainly there was widespread poverty and degradation in the days of Malthus, and he probably was justified in his somewhat pessimistic conclusions. There also is widespread poverty and degradation today, 135 years after Malthus'

environmentalists apparently are shocked by a recently published paper embodying the results of extensive studies that lead to the same conclusion. Some extreme environmentalists seem to think that the word gene should be expunged from the dictionary and that genetic laws should be declared unconstitutional, at least as applied to human beings. But this would open the way to more educational crimes. And there are too many now.

Three other quick quotations regarding the nature of education. "It is our duty to study those matters in which it is also our duty to act," as expressed by the great teacher Arnold. And philosopher John Dewey said, "Some educators suppose they are rendering a service by insisting upon an inherent difference between studies they call liberal and others they call mechanical and utilitarian....This form of philosophic 'dualism' is a further projection of pre-scientific, pre-technological, pre-democratic conditions into present philosophy in a way so obstructive as to demand total obliteration. Here, again, philosophers have a difficult and exacting work to do if they are to take an active part in enabling the resources potentially at our disposal in present science and technology to exercise a genuinely liberating office in human affairs". And, Dewey again : "Scientific method and conclusions will not have gained a fundamentally important place in education until they are seen and treated as supreme agencies in giving direction to collective and cooperative human behaviour". I wish I could say to Dewey, "Well spoken, John", but I cannot, because he is now dead. Fortunately, however, much of his philosophy still is very much alive.

These elementary concepts of education seem simple and sensible, although some of them have had a long and tortuous history. At present, however, most teachers and many educators in the relatively advanced countries would probably subscribe to them in theory and violate them in practice. It may seem hypercritical to emphasize the violations instead of rhapsodizing about the accomplishments of educational concepts and practices, but self-criticism can be a step toward progress. Self-praise and complacency, on the other hand, can result in stagnation and incur the danger of retrogression. The obligations and opportunities of education in the complex modern world are so great that

apathetic, or too timid to be unorthodox in concepts or in methods; they tend to become conformists. It requires courage to be unorthodox, and it requires intellectual initiative and intelligence to become successfully unorthodox. But why change old ways for new ways unless the new ways are better than the old ? We should learn from the experiences of the past and from the experiments of the present; we should be wise enough to be bold without being rash, for the need for effective education was never greater than now.

About two thousand years ago Cicero said, "Fundamentum totius republicae est recta juventutis educatio" : "The very foundation of the republic is the proper education of its youth." The foundation of a successful democracy in modern times is still the proper education of its youth. And in these uncertain and turbulent modern times education toward intellectual enlightenment and spiritual refinement is sorely needed. But can we embellish life unless we can sustain it ? Can we raise our standard of living unless we can raise the level of subsistence in the hungry areas of the world ? And can we raise the level of subsistence unless we raise the level of education ? Possibly we should again ask ourselves : what is education and what is it good for ?

"Education is the natural, progressive, harmonious development of all the powers and faculties of the human beings," according to Heinrich Pestalozzi (1746-1826). Thus, education is the development of inherent potentialities, not a mere matter of imparting knowledge.

But do all individuals have the same inherent potentialities ? As long ago as the fourth century B.C., Plato insisted that individuals differed widely in native ability, in potential attainment and, therefore, in the kind of education they should have, the kind of work they should do, and the privileges they should enjoy; consequently the problem of education was to determine the aptitudes of individuals and educate them accordingly. It must seem obvious to most of those teachers who study students while trying to help them in their studies that good education has only limited power to overcome poor heredity. Or, in slightly more scientific terms, the genes for basic intelligence impose the limits within which education and other environmental factors can be effective. And yet in the United States of America in 1969 many

the human being ?" Is it natural to prescribe exactly how and when grades and marks must be earned ? And who provides the harmony in a compartmentalized and sometimes discordant system of specialized departmental units ? And who tries to make sure that the student is helped to develop all his powers and faculties ? In too many areas of the world the student encounters a rigid system to which he must conform instead of a flexible system which conforms itself at least partly to him. Of course, there has been commendable progress in some institutions, but present discontent indicates that the problem has not yet been solved.

It is a gross misdemeanour to create the impression that education is more potent than it really is. Education cannot do more than help individuals to develop to the limit of their inherent capacities. It is a disservice to the individual to overrate him. And it is a disservice to society to underrate the importance of heredity. In a democracy every individual should be encouraged and helped to develop his intelligence and skills to the limit of his potential, but it is futile and frustrating to try to force him beyond his potential. Education can do much, but it cannot give an individual a new set of genes.

The mutual recrimination between scientists and humanists is at least a gross misdemeanour against education and thus against society. As Dewey said, "Some educators suppose they are rendering a service by insisting upon an inherent difference between studies they call liberal and others they call mechanical and utilitarian", and he concludes that this form of philosophic dualism is so obstructive as to demand total obliteration. There may be differences of opinion regarding the relative merits of the humanities and the sciences in education, but when either group tries to arrogate to itself the exclusive privilege of being social pastor and guide it becomes an arrogant opponent of democracy. Education and society need the services of both the sciences and humanities. Both are humanizing to the extent to which they make people better, happier, and wiser, and neither has a legitimate claim to monopoly in the humanizing.

It also is an educational misdemeanour for scientists to quarrel about the relative merits and values of pure and applied science. Perhaps science itself needs some humanizing.

we must aim at perfection, even though we may not be able to attain it. If we do not aim high, we will never progress far, and the progress of civilization is at stake.

It is rash, of course, to attempt a discussion of so broad a subject as educational crimes and misdemeanours on short notice and in limited space. There is risk of being misunderstood, but, for better or for worse, the die is cast in the hope that at least there may be some understanding of basic motives and meanings.

Crime, as used here, connotes a gross violation of sound principles or practices in education; misdemeanour connotes a minor offense. There may be crimes of omission or of commission—failure to perform a duty or wrong doing in its performance. The credibility of the witness for the prosecution in this case may be questioned; if there are errors in his testimony, they are errors of judgement but not of fact or intent. After all, opinions are only opinions, but facts are really facts. And it is fact that no country or area in the world is without educational sin, although some countries are more sinful and in more ways than others. The generalizations in this paper, however, are based on observations and experiences in various countries and within certain international organizations. Some educational crimes may be characteristically national, but crime in education is international.

The greatest of all educational crimes is one of omission—the failure of some presumably civilized countries to provide education for their youth. Some spend money freely for ostentatious luxuries but fail to spend it for education. And then they boast about their culture. Slightly less culpable are those countries that pay their teachers starvation wages and then expect perfect teaching performance. Any society that fails to educate the young that it itself produced commits a crime against humanity and a misdemeanour against itself.

And even those countries that do have a well-organized educational system often commit misdemeanours against education. Do they really implement the educational ideal that most of them profess—"the natural, progressive, harmonious development of all the powers and faculties of

sitions, from preconceptions, and from prejudices in the consideration of our problems ? Can we consider all of our administrative and educational problems from two points of view : (1) the students to be educated; and (2) the society which is helping to educate them ?

Presumably our primary obligation is to develop people who know and who can do, scientists and technologists. Are we giving our students a sufficiently broad and deep education in science so that they may carry scientific understanding into their technology and thus be better technologists ? And are we doing our best to develop future scientists who can solve problems and build the foundations for new technologies which will be needed in this rapidly changing world ? And are we developing educated men, with perspective, vision, and purpose ? If these are our aims, are we doing everything possible to accomplish them ?

Society needs scientists and scholars; it needs technologists and teachers. It needs the first two to furnish the factual and conceptual basis for making science and scholarship functional, to convert potential social values into actual social values. And here we come immediately into contact with the age-old question regarding individual freedom and social obligation. Is it sufficient for scientists and scholars to learn, know, think, understand, and to develop concepts and philosophies which are compounded into wisdom ? Or do they have an obligation not only to be wise, but also to act wisely and usefully in helping society to utilize their wisdom ?

This question is of vital importance in democracies, which permit freedom of choice on the part of individuals but which must also depend on the intelligence and wisdom of individuals for the success of democracy. The individual who accepts the benefactions of a society has the obligation to contribute intelligently and ethically to that society, for the culture of a society will not rise higher than that of its component individuals.

In order to contribute, we must have something to contribute. Some choose to be technologists; some to be scientists; some aspire to scientific scholarship; and some aspire to become productive scholars. There are differences

To some pure scientists the degree of respectability in science is in inverse ratio to its practical human values. Presumably the "pure" scientist is motivated by curiosity, and curiosity should be kept alive; but people must be kept alive and healthy also, and science must do its part. Some scientists, therefore, must also be motivated by a desire to render social service. Who shall say that one is a higher type of activity than the other ?

There are many other educational sins, related both to concepts and methods : the sin of requiring knowledge without understanding; the sin of encouraging absorptive rather than productive scholarship; the sin of killing curiosity; the sin of professorial volubility and student silence; the sin of making verbalism epistatic to sense realism; the sin of the professors who want only research grants but do not want to teach; the sin of the universities that emasculated their colleges of agriculture; and others too numerous to mention. And speaking of colleges of agriculture, I quote excerpts from a paper by myself on the subject :

The American agricultural institutions are now asking themselves : what should we teach and how should we teach ? There is strong pressure to include more "liberal" studies; but there is no general agreement as to what liberal studies are. The pre-occupation with "the problems of teaching" might better be "the problems of learning". At any rate there is growing recognition of the multiple aims in education, with many fields of specialization and elective courses within each; and education is closely associated with research and with extramural education. The democratic ideal has developed of "education for all, to the limit of ability and of desire fortified by will".

We have threaded our way along historical paths and by-ways toward the idea of naturalism and liberalism in education. But what is naturalism and what is liberalism in agricultural education ? Possibly we can answer by asking ourselves a series of questions : what are our aims; what is the content of our education; what are our methods; and what results do we expect and get ? In considering these questions, possibly we can develop a "new liberalism of our own".

Can our "new liberalism" emancipate us from presuppo-

the scientists; we have made provision for technologists, but have we made sufficient provision for basic education in sciences in our undergraduate schools ? If not, what is the source of our future agricultural scientists ?

And what about scholarship ? What is scholarship and what is it good for ? A common definition of a scholar is "a person of thorough scientific or literary attainments". Would it not be better to substitute "and" for "or" ? But is this attainable in one person ? The answer depends on the meaning of "thorough". Surely it should be possible for scientists to have at least a comprehension of the meanings and values of literary or liberal studies and for humanists to have some comprehension of the meanings and values of science. Society urgently needs not only science but the "scientific method" in studying and solving its problems. And so it seems urgently necessary that scientists and technologists should have enough of the elements of a liberal education in order that they may contribute not only to the material development of society but also to its complete cultural development. Are we doing our full duty to the students and to society unless we "liberalize" agricultural education ? The history of agriculture, the meaning of the fine arts, and the meaning of philosophy could well be subjects in which attempts are made to develop orientation, possibly in non-orthodox ways.

Whatever our basic concepts, the aim in higher education in general should be to develop a sense of scholarship. Higher education in agriculture has a dual obligation : (1) to promote productive scholarship—"the habitual application of an adequately informed and self-disciplined mind to the solution of problems, especially when supported by a high standard of ethics and given moral purpose by a desire to render social service"; (2) to capacitate technologists, teachers, and extension specialists to transmit the results of research to farmers and others in the most effective ways.

And may we be forgiven our educational sins and sin no more !

in interests and aptitudes, and one of the functions of education is to help individuals choose those fields in which they will be happiest and most useful. There should be no invidious distinctions : many good technologists have neither the interest nor the aptitude to become scientists; and many good scientists have neither the interest nor the skill to become good technologists. Some pure scientists may disdain "applied science," or technology, but scientific knowledge plus ability to apply it could be considered a higher accomplishment than knowledge alone. And here we encounter an important question.

Are technologists merely trained or are they educated scientifically ? In educational procedures in agriculture, do those who specialize in technology understand enough of the scientific basis ? Is it worthwhile to study sciences basically ? The scientific basis for agricultural procedures is constantly becoming deeper and broader; hence technologists are continually confronted with new problems. The better they understand basic scientific principles, therefore, the better they can meet the problems. Technology is continually incorporating more science into itself and the scientific base is continually being deepened and broadened. Technology is continually improving methods for doing things and science is continually finding new things to do. The progress of agriculture depends on both.

Scientists presumably do research. And we continually hear the statement that there must be more basic research. What do we mean; what is basic research ? "Basic research is an intelligent attempt to find out all that is knowable about certain phenomena or to find out all that needs to be known to solve complex problems permanently". Obviously, a research scientist must know what has been done, what needs to be done, and how it can best be done; he must have a thorough knowledge of his scientific field and of methods of investigation. He must have knowledge, curiosity, scientific imagination, inventiveness in methods, industry, persistence, and both critical and synthetic ability. Such people are relatively rare. How do we identify them in our schools, and how do we help them to develop their talents ? Is there provision in our agricultural schools for specialization in agricultural sciences or only for specialization in certain fields of technology ? We need both the technologists and

Address

P. N. MEHRA*
D.SC. (PB.), PH.D. (CANTAB)

I feel it a privilege to be invited to address a galaxy of agricultural scientists who have assembled here today to deliberate on various aspects of the development of agricultural education and research in this seminar.

The situation on our food front, as everyone knows, is extremely grave. In fact, it has been for sometime, but this year has been the climax which has witnessed the starvation and famine conditions prevailing in some parts of our country, especially in Bihar. It has been ascribed to the wrath of the rain God who was not merciful enough to let us have sufficient rains for our crops to grow. It seems to me an irony that while the floods devastate and cause havoc in certain parts of the country, other parts suffer because of insufficient rains. Why cannot our water resources be properly harnessed to our advantage ? Much of the land lies uncultivated which could certainly be brought under plough if irrigation facilities existed. Instead of managing our home properly we have been so accustomed to go with a begging bowl for food from other countries that it has become a fashion with us to do so year after year and we feel hurt if our demand is not met as if it were our birth-right to get food from others. This exasperating state of affairs must end, the sooner the better, for our national prestige and honour, and for the conservation of our already scarce resources.

It is a pity that the authorities have awakened to the need for agricultural development rather late. This should have been given the highest priority in our First Five-Year Plan and if that had been thought of well in time we would not have been driven to the plight that we are in today. Be that

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Chapter I

Agriculture Education and Research in India†

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I am happy to be with you because today another group of persons trained in the agricultural sciences will be receiving their degrees and leaving the portals of the University to take up tasks for the improvement of agriculture in our country. My pleasure is heightened by the fact that this Convocation pertains to a University which, though young in years, has already made a substantial contribution to agricultural research, teaching and extension in India. With the support of the Government and the people of the State who have a reputation for sturdiness and common sense, the first Vice-Chancellor**; was able to lay a very solid foundation for the work of the University. The present Vice-Chancellor, Dr. M.S. Randhawa, is well-known for his great knowledge and wide interest in various fields and for the remarkable way in which he combines high ideals with practical ability. His qualities of leadership, I am confident, will enable the staff and students of this University to attain yet greater heights of achievement.

Perhaps the most important task before the country at this juncture is to place its agricultural production—I am using the word 'agriculture' in its broader sense—on a firm footing, so that the people of the country and our domestic

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†Adapted from the Address read at the Fifth Annual Convocation of the Punjab Agricultural University, Ludhiana, held on 19th March 1969.

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**Dr. P. N. Thapar.

as it may, it now behooves our agricultural scientists to face the task with courage and determination. Already a start has been made in many universities and institutions and this University has set up some fine traditions in evolving new varieties of *bajra* and wheat which seem to be evoking much interest in our farmers in this part of the country for their high yield. However, the best in this effort, I believe, is yet to come. But such high-yielding strains can become of practical utility only if the farmers are supplied with adequate irrigation water and quantity of fertilizers, for, a variety that must yield heavily also must consume heavily.

Let me do a little plain speaking in another aspect. Agricultural research divorced from basic or fundamental research is bound to prove sterile in the long run. Due emphasis, therefore, shall have to be given to both if we have to reap a rich harvest. It is like the two wheels of a chariot. One wheel, by itself, however, strong is unable to keep the pace forward for progress. The results of basic research have to be applied consistently for human benefit. It has been so in all the sciences. For example, what rich dividends have accrued from a purely fundamental research done by Mendel during the latter half of the last century on the garden pea !

I am sure this gathering will give sufficient emphasis on the methods of imparting agricultural education to our students—the future scientists of the country—to stimulate in them a real zest and passion for a practical approach to the problems confronting the country rather than merely imparting them theoretical education divorced from realities, which in the present context has become completely out of date.

If we have to survive, the problem is to be faced on all fronts; harnessing of our water resources, bringing more land under plough, development of high-yielding strains suited for particular conditions of soil and climate, adequacy of fertilizers, proper orientation of our teaching and research and above all dissemination of the knowledge gained through scientific pursuits amongst our farmers. But this indeed has to be coordinated with a check on our population explosion.

As a biologist, I am deeply interested in this science both from its fundamental and applied aspects. I am eagelry looking forward to the success of this seminar through fruitful discussions and deliberations.

industry. When Independence came to India it was found that while we needed to make rapid advances in many fields we were handicapped by the prevailing large-scale poverty and misery. It was in this context, that the maker of modern India, Jawaharlal Nehru, once said : "I do not see any way out of our vicious circle of poverty except by utilising the new sources of power which science has placed at our disposal."

It is indeed by application of modern scientific methods that we are now witnessing the beginnings of a change in our agriculture. Although, keeping in view its paramount importance to this country, agricultural research and education have not been supported as fully as they deserved in the past, yet with whatever resources were available our agricultural scientists have succeeded in giving us high-yielding varieties or hybrids of wheat, rice, maize, *jowar* and *bajra*, together with improved agronomic techniques for getting the best out of them. The new dwarf high-yielding fertilizer-responsive varieties of wheat and rice were identified after trials with thousands of foreign varieties; they represent a feat of genetical engineering to provide a new morphological frame so that the plant carrying a heavy grain-load would not lodge when high winds followed irrigation. In the case of maize, *jowar* and *bajra* our scientists used the phenomenon of hybrid vigour—known to ancient man in the production of the hardy but sterile mule by crossing the mare with the donkey—to break the existing yield barriers in these crops. The yields of *jowar* and *bajra* used to be pitifully low at one time but now the popular hybrids bring bumper yields. Along with the new varieties and hybrids developed by the plant breeders, agronomists have by experimentation introduced new agronomic techniques for realising in the field the genetic yield potential inherent in the new types. One of the very exciting developments in agriculture is the multiple cropping made possible, especially in the irrigated areas, by the team work between agronomists, plant breeders, plant pathologists, entomologists, biochemists and agricultural chemists, and others. In order to make possible the cultivation of two, three or even four crops in a year in certain regions, new strains of food crops are being 'designed' which mature in a shorter life-span without a decrease in yield, which are insensitive to photo-period so that they can be adapted to a wide range of conditions and seasons, which have a better

animals may be assured of adequate food supplies of the right kind, and also that the raw materials required by our trade and industry become available. Many of the practices as well as the tools employed in our agriculture had their genesis in the inventive genius of our ancestors going back to the Vedic Age. It is quite clear that if we are to increase our agricultural production we will have to adopt a modern agriculture based on improved technology, the latter being derived from scientific knowledge obtained by research. There are of course many difficulties in helping the more than 60 million farming families of our country to change from traditional methods to new ones, and in making arrangements for the supply of the necessary inputs and sound technical advice to them.

At the same time we must recognise that we have also been endowed by nature with some very precious assets. As we all know, all food in the first stage is manufactured by plants which are the only living organisms capable of converting solar energy into chemical substances and thereby serving as the primary source of all energy. In fact, it has been said that all animals including man live on the earth as the 'guests' of green plants. In the tropical and subtropical areas of the world there is abundant sunshine in contrast to the conditions prevailing in the temperate regions. Another important asset which we possess is the fact that we can raise more than one crop on the same field in a year. Such an intensity of farming can be followed without damage to soil fertility or long-term productivity if appropriate practices like the incorporation of plant wastes and other organic matters are adopted. This type of intensive cropping is of course possible only in areas with assured irrigation facilities but we now have nearly 25 million hectares in India with good irrigation arrangements and, therefore, it should not be difficult for us to produce a large amount of food and agricultural products per year if the requisite inputs are made available. Another way in which we can judge the naturally favourable conditions for plant growth in our country is the fact that we have over 20,000 species of flowering plants i.e. a much larger number than many countries with a much greater land area such as the U.S.S.R. However, in spite of these favourable factors, our country for sometime past has been experiencing grave shortages of food for man and animal, and also of materials required for export and for

industry. When Independence came to India it was found that while we needed to make rapid advances in many fields we were handicapped by the prevailing large-scale poverty and misery. It was in this context, that the maker of modern India, Jawaharlal Nehru, once said : "I do not see any way out of our vicious circle of poverty except by utilising the new sources of power which science has placed at our disposal."

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the field of agricultural research and education which has contributed to the encouraging picture which we see today.

It is obvious that the fostering of sustained agricultural growth makes necessary a continual improvement in the capacity of the farmer to apply an increasingly elaborate set of technologies that will involve larger quantities of inputs which must be applied with ever greater precision and more exact timing. This means, naturally, that agricultural training must take cognizance of this fact and provide for a larger number of courses in agricultural colleges, which have to be suitably selected and tailored to suit individual requirements. But in trying to improve the content and variety of our courses we must be careful to see that, in this machine age, we do not make our Universities merely mills or factories for turning out graduates and post-graduates. We need scientists, teachers and extension men who will also be responsive to other values of human life. Here, I would like to refer to a charming story for children which appeared in an European magazine but also had a message for grown-ups. It is about a railway train which invariably reached its destination late to the great annoyance of both the passengers and the station master. Time and again, the train promised to arrive at the scheduled time but this did not happen. The difficulty was that it took a great interest in the things it encountered on the way. It then decided to offer an explanation to the passengers whenever the train stopped. Thus, it stopped, to listen to the first nightingale otherwise the whole spring would be lost; it then halted to inhale the fragrance of the first lilies otherwise the whole summer would be lost; and finally it came to a dead stop to admire a sunset, otherwise life itself would be lost; so when the train finally arrived the passengers were able to tell the exasperated station master, "We know that we are late but we might have missed the whole spring, the whole summer, or even our whole life if we had not stopped to look and listen and understand". Of course, this story is not meant to justify lack of punctuality but to teach the need to pause long enough to listen to the singing of the birds, to enjoy the perfume of the flowers, to admire the beauty, almost transcendental, of a sunset or a sunrise.

Again, I would like to refer to another story of a great American educationist who told his successor in office:

grain quality and which possess a higher degree of resistance to pests and diseases than the old varieties.

The availability of new strains with a yield potential previously not thought possible in this country, together with the enthusiasm of our farmers, have enabled the beginning of a break-through in agricultural production. It is true, that this is only a beginning and we have many more problems to solve, not only in the crops which have been mentioned but in many other economic plants, and also in respect of problems relating to domestic animals, fisheries, etc. But there is certainly a new feeling of confidence in the country that with adequate support we can build up a prosperous agriculture and thereby provide a firm foundation for the further advancement of our country. What is not always fully appreciated is the fact that the recent acceleration of research in the field of agriculture and the utilisation of its fruits has been largely due to certain important changes that have taken place. Amongst these have been the reorganisation of the Post-Graduate School of the Indian Agricultural Research Institute in 1958 and the setting up of the Agricultural Universities which have made possible a well-directed large-scale endeavour to solve the farmers' problems in an integrated manner. The recognition that research, teaching and extension in agriculture must be fully integrated has proven to be most significant. Another very important fact which has contributed to recent progress has been the initiation and support of a series of All-India Coordinated Schemes for important crop plants by the Indian Council of Agricultural Research. These projects have provided a suitable framework for scientists, whether working in Agricultural Universities or State Departments of Agriculture or Central Institutes, to collaborate in a very fruitful manner. These projects also provide a mechanism for the testing of new varieties or new agronomic techniques in a rapid and comprehensive manner, covering a wide range of soil and climatic conditions, which previously was not possible. In fact, this approach has been so successful that the Council is now endeavouring to extend its application in other areas including the fields of the animal sciences and of fisheries. The Punjab Agricultural University can justly be proud of the significant role it has played in these All-India Coordinated Schemes. Yet another feature which must be mentioned, is the fine co-operation between Indian and international agencies in

education and extension, there is no doubt that we will be in a position to solve many problems including that of providing adequate avenues of employment. In the report of the Education Commission it is not by chance that one of the chapters bears the heading, 'Education for Agriculture' rather than 'Agricultural Education'. The idea here was that it is not only the farmer who has to be considered when planning agricultural education but the large number of people who, in a modern system of farming, have to assist the man who ploughs the soil such as those who provide agricultural machinery and implements, fertilizers and pesticides, and numerous other facilities which are required. In fact, the suggestion in the Commission's report is that in view of the importance of agriculture everyone in school or college should be given an opportunity to know a little about the place of agriculture in our country, by introducing suitable examples in teaching, and so on.

It has been said that, today, man has attained a new level of awareness and the world realises that plenty and poverty cannot co-exist except with dangerous consequences. It is increasingly aware of the fact that food for man should no longer be treated as a mere statistics based on what he can buy. Enough food of the right type is a fundamental right of man, as precious as the air he breathes. In trying to make this possible within the reach of all and in planning for a smiling countryside in which good crops are raised, healthy domestic animals thrive and that there is sufficient production all round of the materials we need to assure happy homes for the millions in this country, the graduates of this University can surely play a significant part. I congratulate them on the successful completion of their education, and wish them and also all the members of this great University very great success in achieving this great ideal for our country.

"Be kind to your very bright students. One of them will come one day and be a renowned Professor in your University. But be also kind to your not-so-bright students. One of them one day will donate a Science Block to you !" This reminds me that when one goes abroad one often admires the fine buildings and other amenities which have been provided in foreign Universities, in quite a few cases, by past students of that University itself, in grateful remembrance of the training for life which they received there. One misses this a great deal in India. Now that the work of Indian agricultural scientists has made possible a better life for many of our farmers and even industrialists perhaps a few of them will come forward and help their *Alma Maters* to provide better facilities for students.

I have said earlier that although we have made advances recently in agricultural research and production we have a great deal more to do, for instance, there is the whole field of dry farming. As we all know, about two-thirds of our country is not covered by irrigation, and, at least for a long time to come, there will be many areas in our country which will not have an assured water supply. We have, therefore, to do research to find out how dry farming can be made more remunerative so that the farmers of these areas may also benefit from modern science like their more fortunate brethren in the irrigated areas.

I have in this address been referring mainly to the food crops but there are many other crops and fields in which research is necessary. For example, in horticulture, much more needs to be done to improve fruits and vegetables. Interestingly, the Indian Agricultural Research Institute has recently taken up the intriguing problem of producing a seedless mango. Even in food crops there is still much to be done, for instance, the challenge of trying to improve the nutritive quality of the grain. For instance, in the case of rice would it be possible to produce a new variety in which the protein is dispersed in the entire endosperm so that this precious element is not lost when rice is milled ? There are tremendous problems in combating pests and diseases which take a heavy toll of the produce both in the field and during storage. As agriculture becomes more intensive, such problems also tend to increase. However, if we pursue an enlightened policy in relation to agricultural research,

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2. Teachers should have a say in university matters.
3. It should be adequately staffed and equipped.
4. The senate constitution was revised by making a minimum limit of 50 members and the upper limit of 100 members.
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Meanwhile, the Calcutta University was finding it too difficult to manage such a large area, so as a result the University of Punjab was established in 1882 and the one at Allahabad in 1887. The year 1913 was an important land-mark in the rise of Indian universities when the Government of India decided to have a university in each of the Provinces. In 1915, Banaras Hindu University was established as a centre of Hindu learning and culture, and in 1920 Aligarh University was established on the same pattern for Muslim education.

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Traditional and Agricultural Universities Compared-Historical

LAKSHMI M. RAO*
PH.D. (TRONTO)

I would like to talk on the rise of Indian universities and give a little comparison with universities abroad chiefly with regard to their teaching methods.

To begin with, I will take you back to our ancient universities of Taxila, Banaras and Nalanda. There were many more but due to the shortage of space I cannot touch on all, so I choose these three famous centres of learning.

Taxila founded by Bharat and named after his son Taksha, is a few miles west of Rawalpindi. In 700 B.C. it was a great centre of learning. In that University, the Gurus usually had 20-25 pupils each and the boys were chosen carefully, about 16 years of age, and they stayed with their gurus for about 8 years. Even in those days of difficult travel Taxila had students from Tibet, Korea, Ceylon, Burma and the subjects taught were Vedas, Upnashads, logic, astronomy and literature. The 'shishus' revered their 'gurus' and looked after them, and in return, they received their education. In the 3rd century A.D. it was destroyed by the Huns.

Banaras also flourishing in 7th century B.C. was a great centre of learning. The Brahmin gurus attracted students from all parts of India and the same system of education was followed as in Taxila. Meanwhile, at Saranath near Banaras rose a Budhist centre of learning and these two centres influenced each other very much. Subsequently, in the sixteenth century the new School of Dharamasastra was set up in Banaras and it became the centre of Hindu intellect and learning.

Nalanda, near Patna, was at its zenith in 450 A.D. and it became a centre of Mahayana Budhism. It was founded

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by King Sakraditya, a devout Hindu. It was a magnificent centre of learning, for Huen-Tsiang, a famous Chinese student, who studied there describes it as a beautiful place with well kept gardens and halls for study. There weie over 300 rooms for lecturing and the buildings were several storeys high. In the campus were three extensive libraries and an astronomical observatory whose towers rose into the sky. Vedas, Upnashads, Jainism, Budhism, metaphysics, astronomy and astrology were taught. There were 8,500 students and 1,500 student teachers, the ratio being 6:1. Entrance test was so difficult that may be 1 or 2 out of 10 students were admitted. This university flourished and was renowned till it was destroyed by Bakhtyar Khiliji in 1205 A.D. This invader probably mistook it as a fort. As the Northern universities declined due to various invasions there grew up a number of centers of higher learning in the Hindu temples of South India. They were called 'tols' and students lived in mud huts nearby and looked after their Gurus. They were taught more or less the same subjects and no fees were ever charged. The financial assistance came from rich patrons who were interested in education. This was an ideal situation as no outside influence was tolerated and there was complete autonomy, the teaching being the chief attraction. No provision was ever made for women education in the ancient Indian Universities.

In the field of education the next significant period in India was that of the Moguls. Both Babar and Humayun were learned persons and Humayun's sister was a writer. In the Mosques were started schools or Maktabs for the children and Madarasahs for higher education. Women's education which did not exist before was considered necessary in the Mogul period and in the Zenanas, girls were taught to read and write. With Akbar came a great change and he started centres of learning for Hindus also and more Madrasahs for the Muslims. These seats of learning were so coordinated that interested students could attend either—although the Persian script was used in Madrasahs and Sanskrit in the Hindu centres of learning. The students mingled quite freely and influenced both schools of thought. Aurangzeb further set up a number of Madrasahs, and Zebunissas. His daughter who was a poetess, also encouraged these centres of learning. During the time of Aurangzeb the Hindu centres of study and learning were neglected completely.

The modern education in India was really started during the days of East India Company and the British Raj. In 1853 when the Company Charter was received the British started to think seriously about the education of the people in India. Meanwhile the Christian Missionaries had come in and opened schools for boys and girls with English as the medium of instruction but there were no scheduled examinations till Macaulay's 'Minute' was published and Lord Bentick gave the green signal for systematized education with English as the medium of instruction.

Before this, there were two schools of thought and the opinion was divided whether the Persian language and script should be used or English. Raja Ram Mohan Roy, the great reformer, agitated for English as the medium of instruction and the East India Company's declaration that only those who knew English would be considered for posts in their Company, turned the tide in favour of English.

In 1853, the House of Commons requested that the whole idea of education in India be looked into and Sir Charles Wood was asked to study this matter and make a report. So on 19th July, 1854, the famous report known as 'The Intellectual Charter of India' was made and the recommendations were of a dual character. It was recommended that the Departments of Public Instruction be opened in Calcutta, Madras, Bombay, Punjab and N.W.F.P. and that three Universities be established. So the Universities of Calcutta, Madras and Bombay were established in 1857. Calcutta University had jurisdiction from Bengal to N.W.F.P. on the pattern of the London University which was then merely an affiliating University. The Governor of the State was the Chancellor and he appointed a part-time Vice-Chancellor for two years. The Fellows of the University who formed the Senate were chiefly from among the administrators and publicmen. The teachers had no say in the matters of curriculum or examination or anything. In 1857 there were in all 27 colleges in India.

In 1898, London University became a teaching university, so its echo was heard in India also and the Government of India appointed a Commission to look into the matters of education. The following recommendations were made, and implemented by the Act of 1904 :

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education in the school.
2. The School Leaving Certificate examination may serve a dual purpose by also being the entrance examination to university.
3. Scholarships be given to at least 1/3rd of the students.
4. University Grants Commission be formed on the model of the British V.C.G.

1947, the year of Independence, for India hastened a comprehensive inquiry in all aspects of university education. So the University Education Committee headed by Dr. S. Radhakrishnan with 6 colleagues and one British and two American educationists, was formed and they did a detailed study into many aspects of University Education in India. The following changes were recommended :

1. Raising of the level of education in Science Schools.
2. Provision of Occupational Institutes.
3. Raising of the level of admittance and selection into colleges.
4. Advanced Research amenities to be provided in universities.
5 The plight of the teacher was taken into consideration and they recommended suitable salary scales for teachers. The retiring age was pushed up from 55 years to 60-64. So the teacher was given his correct place in college and university for the first time.

Teacher given his place : Act of 1956 passed by the Indian Parliament made provision for the establishment of University Grants Commission, consisting of full time Chairman and nine other members elected by the Central Government.

The event of great importance for the future of University education in India was the appointment on 16th July, 1964, by the Government of India, a 16-member commission of the University Grants Commission to survey and examine the entire field of education in order to realize within the shortest possible period a well-balanced and integrated system of national education. Eminent scientists and educationists from U.K., U.S.A., U.S.S.R., and Japan were associated with this Commission as members and consultants. Recommendations made were :

1. Reorientation of the education system for national

development, for food production, employment, social and political development, and national integration.
2. Pursuit of excellence in all directions; (i) provision of education facilities; (ii) quality of teachers; (iii) selection of students, and out-put of research.
3. Necessity for a rapid growth in the quality and extent of education and research in science and technology for industrialization and productivity.

Here it will be worthwhile reviewing the various teaching methods used in universities elsewhere. The four recognized methods, both in western and eastern parts of the world, are :

1. Lecture method.
2. Tutorial.
3. Discussion method.
4. Seminar.

Most common is the lecture-method, used in most universities in U.K. and India. Lectuı ing is considered an important means of communication between the teacher and the pupil. Tutorial system is the constant communication between the teacher and the taught. It is a great art and is the dominant feature of Oxford and Cambridge Univeısities where instructions must be fully residential. Research is difficult, for the staff are too busy with students. Discussion-with some lectures at the undergraduate stage is common in U.S.A. and is superior to lecture method but requires many more teachers and class-rooms. Seminar method is good for senior classes and post-graduate students, is used in U.S.A. and is coming into practice everywhere. It is a training method and gives self-confidence.

German Universities have their own distinct system of education for over 150 years. The main features are :

1. Lecture to large groups.
2. Practical exercises by Assistants.
3. Seminar for senior students.
4. Unique method of evaluation and examination.

Education for women in universities : East India Company, did not take much notice of girls education probably due to three reasons; (i) Purdah system, (ii) child marriage, and (iii) general indifference of parents.

In 1875, Mr. Kharsetjee asked Bombay University if his

daughter could take matric examination. She was refused. Sometimes later Miss Basu from Dehra Dun asked Calcutta University the same and was refused also. However, in 1877, Calcutta opened its doors for the girls to matric and the two Basu sisters graduated in 1883. The same year in Bombay women were admitted to degree courses in arts, medicine, law, etc.

Mr. Bethurn gave £10,000 for women's education and in 1879, Bethine College was started which was later affiliated to Calcutta University in 1884. The same year, Maharashtra Female Education Society was founded in Poona. At present, there is a women's University in India—the Thackersay Womens University—which is a unique one. In addition to the normal university subjects, instructions in foods, nutrition, child care, and other womens' needs are imparted. In another twenty years most of the Universities were opened to women.

Another important recommendation in the Radhakrishnan Report was that technical education, particularly agricultural education, should be given more emphasis in the country. Later on, a definite policy was formulated and it was decided to have at least one Government financed Agricultural University in each State, where subjects relating to agriculture and rural life should be emphasized.

The first two universities that came up were the U.P. Agricultural University, Pant Nagar, and the Punjab Agricultural University, Ludhiana, in the year 1960 and 1962, respectively. Since then 8 more Agricultural Universities have been raised in other states and more are yet to come. The main faculties in these Universities are Agriculture, Veterinary and Animal Science, Agricultural Engineering and Technology, and Home Science. In these universities the American system of education commonly known as the Trimester System has been adopted.

In India, we have now 66 Universities, 2,572 colleges and over 17 lacs of students.

Traditional and Agricultural Universities compared—Historical

D. R. Bhumbla*
PH.D. (OHIO)

A University has been defined as "A community of teachers and students, where in some way all learn from one another or at any rate strive to do so.

The principal object is "to deepen man's understanding of the universe and of himself—in body, mind and spirit, to disseminate this understanding throughout and to apply *it in the service of mankind*".

The Education Commission has outlined the functions of University in the modern world as under :

—to seek and cultivate new knowledge; to engage vigorously and fearlessly in the pursuit of truth and to interpret old knowledge and beliefs in the light of new needs and discoveries;
—to provide the right kind of leadership in all walks of life; to identify gifted youth and help them develop their potential to the full by cultivating right interests, attitudes and moral and intellectual values;
—to provide society with competent men and women trained in agriculture, arts, medicine, science and technology and various other professions, who will also be cultivated individuals, infused with a sense of social purpose;
—to strive to promote equality and social justice and to reduce social and cultural differences through

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At present : Director, Soil Salinity Laboratories, Hissar.

diffusion of education; and

—to foster in teachers and students, and through them in society generally, the attitudes and values needed for developing 'good life'.

In India, there are 66 Universities and eight other Institutes that are recognised as Universities. Eight of these universities and one of the institutes are recognised as Agricultural Universities.

Within the last seven years a number of States have established Agricultural Universities on the pattern of land grant institutions of U.S.A. In the Punjab Agricultural University Act, 1961, the following have been given as the objects of the University :

(a) making provision for imparting education in different branches of study, particularly agriculture, veterinary and animal science, agricultural engineering, home science and other allied sciences;
(b) furthering the advancement of learning and prosecution of research, particularly in agriculture and other allied sciences;
(c) undertaking the extension of such sciences to the rural people of the State; and
(d) such other purposes as the State Government may by notification direct.

A list of the Agricultural Universities along with the year of their establishment is given below :

1. U.P. Agricultural University, Pantnagar .. 1960
2. Punjab Agricultural University, Ludhiana .. 1962
3. University of Udaipur, Udaipur (Rajasthan) .. 1962
4. Orissa University of Agriculture and Technology, Bhubneswar .. 1963
5. Andhra Pradesh Agricultural University, Hyderabad .. 1964
6. Jawahar Lal Nehru Krishi Vishvwidyla, Jabalpur .. 1964
7. Mysore University of Agricultural Sciences, Bangalore .. 1965
8. Kalyani Agricultural University, Kalyani, West Bengal .. 1965

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The Indian Agricultural Research Institute is one of the central institutes that has been recognised as a University. The functions, responsibilities and organisations of these universities differ to a great extent. The then Punjab Government transferred to the Punjab Agricultural University the entire responsibilities of teaching, research and extension education. The Colleges of Agriculture, Veterinary Science and Animal Husbandry, all experimental stations and the Subject Matter Specialists (Extension Specialists and Assistant Extension Specialists) were transferred to the Agricultural University. In Rajasthan while teaching responsibilities in agriculture and animal husbandry were transferred to the University, a distinction was made between fundamental and applied research (probably nobody is able to draw a line of demarcation). However, the arts, science and medical colleges at Udaipur were transferred to the University. In U.P., the Agricultural University took birth in Terai area. None of the teaching and research activities of the Department of Agriculture and Animal Husbandry were transferred to the University. The University at Jabalpur with nine Campuses is also responsible for agricultural research in the State.

There are some common features of all of these universities :

(1) They have all been established with the main object of improving agriculture of the State on the pattern of Land Grant Institutes where teaching, research and extension are integrated.

(2) All of them have adopted the trimester system with internal examiners (except for theses of post-graduate students).

The Education Commission recommended that every State should have one Agricultural University and the other universities should strengthen faculties of agriculture. The recommendations of Education Commission regarding con-

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*Since then the following two more Agricultural Universities have been established :

Maharashtra Agricultural University, Rehuri	1968
The Assam Agricultural University, Jorhat	1968

tribution of universities to the education for agriculture are :

(1) "The disciplines which infringe and contribute to agricultural development are many, i.e. biology, chemistry, physics, engineering, economics, administration, sociology, law, commerce, etc. Universities should be encouraged to develop courses at the graduate and post-graduate levels in these areas, with special reference to their application to agriculture.

(2) "Universities should be encouraged to strengthen their faculties of agriculture. Care should be taken to see that adequate standards are maintained and that the available resources in men and materials are not scattered thinly over a wide area. Where such facilities exist or are started by universities, arrangements should be made for them to work with agricultural experimental stations situated in the neighbourhood and to involve their faculty members and students in extension education and demonstration programmes.

(3) "We also suggest that steps should be taken to establish a close relationship between some of the agricultural universities and the Institutes. The possibility of developing a faculty of agriculture in an institute should also be explored. There could be an organized exchange on a selective basis, of students and staff, and also some common programmes of study and research could be undertaken. There are a number of areas of research, as for example, those concerned with land reclamation, irrigation and water management, crop processing and storage, farm mechanization and tillage, and others where joint work by engineering and agricultural institutions could be of great value.

(4) "The close collaboration in education for agriculture between the agricultural universities, the Institutes and other universities would be greatly facilitated if the some organization, namely the Indian Council of Agricultural Research, is charged with the responsibility of over-seeing the development of

agricultural education, not only in the agricultural universities but outside them also. The financial support from the Indian Council of Agricultural Research should also be available, not only to the agricultural universities but also for universities and Institutes for the development of education for agriculture. Similarly, the support of the University Grants Commission or the UGC-type of organization we have recommended for technological education should also be available for the development of faculties of natural or social sciences or engineering in the agriculture universities. We emphasize this close collaboration between the University Grants Commission and the Indian Council of Agricultural Research which is of great significance for the development of agricultural education."

Agricultural University graduates constitute a small fraction of total agricultural graduates in the country. Recently a report of an Inspection Team appointed by Government of India to study the working of mushroom growth of agricultural colleges in U.P. was published. According to this report, in U.P. about 3,000 graduates are produced in 25 agricultural colleges when requirements of that State are estimated to be about 1,200. Some departments of Agra University are preparing for M.Sc. and Ph.D. degree with less than 100 books on the subject and practically no journals. Graduates from these universities form bulk of the staff in extension in U.P., Haryana and other neighbouring States. No study has been made about the colleges affiliated with the Punjab and Kurukshetra and Rajasthan Universities. Though the number of colleges is not large, the facilities with regard to staff and equipment will be no better than in U.P. It is high time that the agricultural universities and traditional universities cooperated in improving the standards of education in Agriculture.

In agricultural universities, admission to post-graduate courses is open to pure science graduates. This needs to be encouraged further. However, this has caused a certain amount of resentment among graduates in agriculture because the time spent by pure science graduates in obtaining first degree is much less. In this connection, remarks of

Education Commission are pertinent :

> "In India the first degree in arts, commerce and science is of a much shorter duration 'just like half way degree'. It cannot, therefore, be equated with the first degree in agriculture or engineering or medicine which has a much longer duration. In fact, it is the post-graduate degree in arts, commerce or science which are comparable with the first degree in agriculture, engineering or medicine".

In most countries, the duration of the first degree whether in arts, science, agriculture or engineering is the same. This pattern needs to be followed in India also. Perhaps a beginning could be made with the science degrees.

Coordinated projects in certain subjects such as Plant Physiology, Plant Pathology, Entomology, Physical Chemistry and Biochemistry, Biophysics should be started. In many universities a number of research projects connected with agricultural sciences are in progress. Some of these projects in Plant Physiology, Plant Pathology, Microbiology, Biochemistry and Agricultural Chemistry are financed by I.C.A.R. More coordinated projects in these subjects should be started where scientists in agricultural and traditional universities can cooperate. In post-graduate classes in the said subjects, graduates in agriculture should be encouraged and given due credit for the courses already taken by them. Exchange of teachers for certain specialised courses or to conduct research also needs to be encouraged. The research projects taken up by the students and the staff should be problem oriented and aimed at furthering the economic needs of our country.

Traditional and Agricultural Universities compared—Educational System

M. K. MOOLANI*
PH.D. (ILLINOIS)

Introduction : India is primarily an agricultural country where more than 70 per cent of the total population depends on agriculture which makes it the most important means of livelihood in the country. Thus, agriculture is of paramount importance and our chief object should be to consider the general problems of devising an agricultural education programme so that there shall be overall improvement of the millions of masses in the rural areas. Agriculture must be re-organized and rationalized in such a way that with proper science and technology, more production per acre can be achieved. Agricultural Education system in the country needs immediate changes to coordinate the agricultural education at all the levels, i.e. School, College and Universities. Since 85 per cent of the people demand such education at a School level, more Agricultural Schools are needed and these are pre-requisits to keep link with Agricultural Colleges and Universities in the country.

Present position : The need for research, the training of Agricultural graduates and the extension programmes with the farming community have been recognized in this country for sometime. The traditional universities have handled the training of agricultural graduates and the State Departments of Agriculture and Community Development Blocks have controlled the programme of research and extension activities, respectively. At present there are about six dozen Agricultural Colleges in the country but they are much divorced from experimental research stations and

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extension organisations with the result that there has been much criticism from important bodies like University Education Commission, Joint Indo-American Teams, etc.

It was about 50-60 years ago when Agricultural Colleges in the four regions of the country were established, at Lyallpur (now in Pakistan), Kanpur, Poona, Coimbatore, Nagpur, and Sabore (Bihar). The Indian Agricultural Research Institute was started at Pusa (Bihar) in the year 1905 which was shifted to New Delhi in 1936. Subsequently, the need for agricultural education at the college level was realized and more Agriculture Colleges and Experimental stations were established by 1920. Research work on important agricultural crops has been carried out for the last 40 years under the control of the Directorate of Agriculture in various States, but all the research work has been confined to departmental files. The results obtained were not translated to the farming communities, to improve agriculture on scientific lines.

It was only after the partition of the country in 1947 that the need for reorganisation of agriculture on scientific lines was realized and with this in view, the Community Development Project and National Extension Service were established by 1951-52, after which extension has played a vital role in carrying over the research data to the cultivators for improvement of traditional agriculture. With all these changes, there has not been effective coordination between teaching, research and extension. Unless our agricultural development programmes are overhauled and reoriented, they will not meet the needs of the cultivators to attain significant increase in agricultural production.

Triangular approach to the problem : It appears that three levels of educational opportunities should exist in the reorganised agricultural education system. At the base should be a strong vocational programme available to the cultivators, their sons and daughters. This would be tied up with the basic school system preferably at the High School Level. Vocational agriculture is the training given by High Schools and is meant for those who are engaged in farming and also for others who are preparing to enter the occupation of farming. Next would be the Institutions like the present basic

schools and extension training centres in which large numbers of youngmen and women are trained primarily for work that would improve rural life. Existing colleges cannot possibly train all the needed staff but as the facilities are expanded, colleges could take over the responsibility of training the village level workers. At the third level, also at the apex, would be University teaching in agriculture, animal husbandry, veterinary science, home science and rural industries of the basic arts and sciences.

Traditional Universities and their characteristics : At present, most of the Agricultural Colleges in our country are affiliated to autonomous universities of the traditional type. They are characterised by the rigidity of the syllabii, the standard type of examination conducted by external examiners and inadequate teaching programmes and facilities in lecture rooms, laboratories and fields. It is shocking to observe that quite a few Agricultural Colleges with less than 50-acre farms and ill-equipped laboratories are offering B.Sc. and M.Sc. courses. This will certainly lower the standard of Agricultural Education. The traditional universities hold examinations only once a year which means examining at the end of the year. Therefore, for the whole year, there is a lack of continuous learning and the fate of the students is at the hands of examiners who come only once a year to examine them. There has also been no coordination between research and extension with the result that there has been no two-way flow of the problems of the cultivators coming to the laboratories for solution.

Report of University Education Commission : With the increasing demand for agricultural graduates, the University Education Commission, in 1949, further detailed out the functions of Agricultural Colleges. These were to provide instructions, practical training and research and to promote extension work. The Indian Council of Agricultural Education was set up to promote the objectives laid down by the University Education Commission. Though the I.C.A.E. was established in 1951, its work started only in 1956 after the second meeting of the Council. The Indo-American Team of Agricultural Research and Education recommended reorganisation of agriculture on the pattern of the Land-Grant Colleges in U.S.A. and with this, the Agricultural Universities were born in our country.

Important features of Agricultural Universities : The most important features which distinguished the Agricultural Universities from the Traditional Universities were :

1. They gave due recognition to the needs of the farmers and assumed a responsibility to work towards economic development and improving the standard of living of the people.
2. Besides teaching, the staff were also responsible for carrying out fundamental and applied research which was further extended to the cultivators through effective extension organization and the problems of the farming community were fed back to the research laboratories and this two-way flow was maintained.
3. The extension programme was an important limb of the University and was fully integrated with teaching and research organisation so as to keep a very effective two-way flow.
4. The course curricula and practical training programmes were modified in such a way as to orientate the needs of the State with the needs of the students/trainees.

The Agricultural Universities are autonomous and free from administrative restrictions and give full recognition to qualified teachers and have the authority to modify the course curriculum to meet the changing pattern of Agricultural Education.

Coordination between traditional and agricultural Universities : In view of the merits and demerits of these two types of Universities controlling Agricultural Education in different States, it can be very well realized that the Agricultural Universities which made a start only in 1962, have really made great headway in changing the pattern of Agricultural Education in our country. Effective coordination between the traditional and Agricultural Universities will bring more improvement into the changing pattern of Agricultural Education Programmes only if the best points of Agricultural Universities are taken up by the traditional universities with immediate effect. The changes which can be suggested in the Education Programme of Traditional Universities are :

1. *Course curriculum :* The courses are very rigid, over-crowded, and are taught irregularly. Hence in many cases, the entire course is not covered by the staff and the student community is left to the mercy of the external examiners who evaluate the performance of the students at the end of the year. Certain proportion of marks, if given through internal assessment, might help in making the students more regular in studies.

2. *Improvement in Examination :* The Trimester or Semester systems should be adopted. In this way, regular examinations are held every three months. It appears this method of examination is superior to the old type of annual examination. Students are forced to continuously learn rather than learn at the end of the year.

3. *College accreditation :* (i) Immediate steps should be taken by the University Grants Commission or by the Indian Council of Agricultural Education to stop mushroom type of colleges so that the same budget and staff may be diverted to strengthen the good existing colleges and to improve the standard of teaching.

(ii) Unless the institutions meet a rigid and adequate standard of requirements, they should not be allowed to teach agriculture.

(iii) All Colleges should be required to meet a minimum standard in staff as measured by training and achievement a library, adequate for the student body and staff, a physical plant, good equipment and research programme to meet the needs of the State and enlightened administrative staff with freedom to act.

4. *Administration in Colleges and Universities :* For the improvement of teaching and research, colleges and universities should be given full autonomy and academic freedom. In most institutions, bright young staff is generally suppressed and cannot express its views and good research workers are often discouraged and not given full facilities. This has become a root cause of handicapping good programmes of research. In many cases, the administrators are not given full authority to buy even minor items which are so important in teaching and research. This has hampered

the procurement of equipment, purchase of necessary appliances for the routine type of teaching and research. In such cases the authorities of the Institutions should be given full academic freedom, administrative powers and responsibility to act in the interest of work.

5. *Staff participation in Seminar/Symposia :* The experience of the last five years in Agricultural Universities has shown that staff participation in Seminars/Symposia is extremely effective in learning and understanding the teacher taught relations.

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Traditional and Agricultural Universities compared—Budget and Accounts

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Administrative Set-up : Decentralization of powers is the essence of the budgetary and accounts system of this University and this is how it is entirely different from the Traditional Universities. Another significant change is that the Vice-Chancellor and the Registrar are relieved of the work concerning accounts and finances at the headquarters and all such work is concentrated with a separate Finance and Accounts Officer of the status of Registrar and designated as Comptroller. The latter also acts as the Financial Advisor to the Vice-Chancellor and possesses the status of the member of the Finance Committee, the highest financial authority of the University. The Act and Statutes of the University provide necessary rights and duties for the Comptroller to enable him to discharge his functions.

The Comptroller has got with him a number of Assistant Accounts Officers, Incharges of different sections like that of Budget, Accounts and Pay. These are the counterparts of Assistant Registrars (Accounts/Budget) in other Traditional Universities, who are attached with the Registrar.

Since the Heads of Departments have been given the powers of Drawing and Disbursing Officers to the extent of their budget allotments (which is also decentralized with them), they are given adequate staff on the accounts side to assist them in discharging their responsibilities. Every college has been given one Assistant Accounts Officer/Administrative Officer besides the subordinate staff to help these offices. It

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may be amplified here that while accepting the principle, that decentralization of powers with the Deans/Directors/ Heads of Departments help them in taking expeditious action, this University has equally realized that these technical officers should be given adequate and qualified staff for helping them to discharge their administrative and financial duties.

Besides this, the University has prescribed departmental examinations for teachers and other technical employees of the University and the syllabus practically covers all the financial rules and regulations which the people holding the authority should be acquainted with. This examination has been very popular and has reduced the chance of technical people claiming ignorance of the necessary rules and regulations for their day-to-day activities. It is also important because it will be too much to expect from an officer to hold decentralized authority without expecting him to know the manner in which that authority is to be exercised.

The staff dealing in accounts and financial work with the Departments (though administrative under the control of the respective officers/departments) has been placed under the technical control of Comptroller. The latter by way of periodical inspections studies the efficiency of the accounts staff working in the various departments. The annual confidential entries of such staff are to be given jointly by the Comptroller along with their administrative heads.

In this connection, it may be pointed out that the Comptroller adopts one more important method to keep up the efficiency of such staff working with the Departments and to help the Departmental heads in relieving them of the accounts and financial worries of their respective departments; this University is following the pre-audit system in which no payment can be made till it is passed by the independent Government Auditors of the Examiner, Local Fund Accounts, Punjab/Haryana. The Comptroller, by keeping close and healthy collaboration with the auditors always tries to ensure that :

(i) the accounts staff bringing their claims for pre-audit to the auditors are fully equipped with the necessary material;

(ii) the auditors attend to them promptly;

(iii) the objection, if any, is promptly and amicably settled; and

(iv) that the payments are not held up.

It will be interesting to note that inspite of about 70 Drawing and Disbursing Officers, involving annual budget of Rs. 4 crores, there are very few instances when the Comptroller has to intervene to expedite the payments and we strictly follow the schedule of payments within ten days from the receipt of claim. The Comptroller also gets monthly returns from the Drawing and Disbursing Officers to keep a continuous watch that the payments are made within ten days of the receipt of the claim.

There are sufficiently tough qualifying written as well as verbal tests for Clerks, Accountants and Assistants, etc., before they are recruited. Over and above this, they have to qualify in the departmental examinations which are of high standard to ensure that the staff working in the University is made to acquire the thorough knowledge of the various rules and regulations with which they have to deal with in the day-to-day work of the University. Incentives are also prescribed for those who pass such examinations with credit and this helps the University to groom up more and more of the staff to handle the important work in the offices.

Sufficient Administrative and Financial powers required by the Heads of Departments/Deans or any other officers of the University below them have been given to them by the Act and Statutes of the University to enable them to carry on their work with regard to teaching, research and extension education without involving any delay or red-tape. The Vice-Chancellor is also given considerable powers normally exercised by the Senate and Board of Management in other Universities with the result that it helps in expeditious working. If there is anything to be referred to the Finance Committee/ Board of Management such matters are not delayed because the meetings are held almost every month.

Budget and grants : The estimates of expenditure for the subsequent year are called for from the Deans and Directors and Heads of Departments for scrutiny in the Comptroller's office. After detailed examination, the schedules of expenditure both for Plan and Non-Plan are submitted to

the concerned State Governments for making provisions in the State Governments' budget. The Budget then is submitted to the Finance Committee/Board of Management for their approval within the resources expected from the State Governments who mainly finance the University. No expenditure can be incurred unless the budget is approved by the Board of Management. The sanction for the university which is included in the State budget is to be approved by the State legislation before the grants are released. The Budget Estimates also include the proposal for expenditure to be incurred for schemes financed by the Indian Council of Agricultural Research, Government of India and any other financing agency. The receipts of the University unlike traditional Universities are insignificant as they form only less than 10 per cent of the total budget. The State Governments provide for gross expenditure in their State budgets for the University and while releasing the grants release only the net grant deducting anticipated receipts. The University gets grants from resources other than the States directly. The University authorities have been given adequate financial powers to reappropriate funds from one scheme to another with regard to the State schemes. The grants are to be collected from the State Governments quarterly. Since income of the University itself is not very significant, it has to depend mostly on the Government grants. Though the grant should be released every quarter but due to procedural delays on the part of State Governments concerned, the Comptroller has always to be on his toes to ensure that the grants are collected in time and that the payments for salaries and other bills are promptly made. Similar difficulty is sometimes found with regard to the grants from I.C.A.R. where again due to procedural delays, the grants are not released promptly. Sometimes, even the sanctions of some of the I.C.A.R. and Government of India schemes are not received till the beginning of the year when the schemes are to commence. If these authorities could ensure issue of sanctions before the commencement of the year and release the grants promptly, it could help in more effective implementation of the schemes and save the University authorities from avoidable efforts in this direction.

Besides the pre-audit of accounts, the Examiner, Local Fund Accounts, Punjab, Haryana do post-audit of the accounts which includes checking of receipts, adjustment of advances

and checking of classified accounts. After this, a certificate known as "Grant Utilization Certificate" is issued by the Examiner. By prescribing a schedule for compilation of accounts and their prompt post-audit, the certificate is obtained from the Examiner latest by the month of October/November of the subsequent year. It may be interesting to note here again that the University during the last three years has obtained flawless audit certificates and no amount has been held under objection thereby ensuring that the grant for the subsequent year is received in full by the University. According to our system, agreed with the State Governments, the grant for the final quarter, that is, the fourth quarter of the year is not released to the University till the Grant Utilization Certificate for the grants released to the University during the previous year has been submitted to the State Governments.

At present, there is one more different feature of grants in this University as compared to the Traditional Universities in the sense that this University being a common link serving four different regions, is financed by four different States/Union Territories, viz., Punjab, Haryana, Himachal Pradesh and Chandigarh and the grants are to be collected and expenditure is to be incurred in the respective regions in the agreed proportion/decision of the Board of Management. As soon as the budget is approved by the Board of Management, which is got done in the month of March every year, the departmentwise budget is intimated to all the Heades of Departments by 1st April, every year. This enables the Departments to know well in time the funds available with them. As regards the filling of vacant new posts, we even go ahead to complete preliminary formalities before 1st April (to avoid loss of time).

The Statutes give enough authority to the Departments to reappropriate minor savings. For other reappropriations, Comptroller follows strict schedule to ensure that those who need additional funds get them in time and the savings are properly utilized elsewhere.

The grants are received in the name of the Comptroller who is responsible to ensure their prompt collection and get them credited in the State Bank of India where the University funds are kept in current account.

Land-Grant Universities in America

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The concept of an agricultural university in America was born with the passage of the Morrill Act, known as the Land Grant Act in 1862—and signed by President Abraham Lincoln.

The Land-Grant College, established under this act brought into being an entirely new concept of education in America.

Early American Universities emphasized the social, moral and religious development of the student. The denominational college, with its faculty consisting primarily of clergymen, played an important role in this early system of higher education. The college faculties were deeply interested in the religious, moral and social welfare of the student, and in the development of the mind. The rise of the German University in the nineteenth century brought added emphasis to the need for training the mind. Mental discipline was the order of education—intellectualism was upper most in educational programmes. At this time higher education was available only to those who could pay for it. Each individual needed to finance his education since it was of no concern to the State or National Government to assist.

With the passage of the Morrill Act in 1862 and subsequent establishment of a Land-Grant University in each State we had in America the advent of a new philosophy of education, the beginning of democratic education. It was the beginning of colleges for the sons and daughters of the common man—and later with the passage of the Smith Liver Act in 1914 creating the Cooperative Extension Service

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1. The United States Department of Agriculture Act also *in 1862 creating the United States* Department of Agriculture.
2. The Hatch Act of 1887 which created the Agricultural Experiment Stations.
3. The Smith Liver Act of 1914 which established the cooperative extension service.
4. The Smith-Haghes Act of 1918 creating the vocational schools in secondary schools in agriculture and Home Economics.

You know the rest of the story—how the Radhakrishnana Committee after careful study and a trip to U.S.A. and with the support of two Indo-American teams recommended that India develop its own agricultural universities and, so far as was practical, pattern those universities after the land-grant pattern. We have seven such universities in India, today, Punjab Agricultural University being one of the important ones.

You are aware of the importance of biological sciences—the science of physical life—plant and animal life—its morphology, physiology, origin and distribution, to development of a scientific agricultural education and research program. Many American Universities attach sufficient importance to this area to give the faculty status of a college of Biological Sciences. At may home university a new College of Biological Sciences incorporating Biochemistry, Botany, Microbiology, Zoology, Entomology and a division of Bio-Physics was started one year ago. Can you name any of the sciences more important to a program of agricultural education, both resident teaching and extension education, and agricultural research ? Your deliberation here during these days will be a valuable contribution in delineating the role and function of excellent teaching of biological sciences as a vital part of a scientific program in agricultural research and education in India.

I would like to devote some attention to Goats and Objectives for Agricultural Universities in Developing countries with full credit to the CIC-AID Rural Development Research Project dealing with Agricultural University development in all the developing nations of the world.

Seven American Universities are involved in this research project with leadership to that phase dealing with India, Pakistan, Turkey, Afghanistan and Iran under the direction of Dr. Jack Rigney, stationed in New Delhi during the past eighteen months. The following is a quite from that study—because I feel it important to make the statement a part of the record of this school.

The Land Grant system has made an outstanding contribution to the agricultural economy of America, and it has attracted the attention of developing countries around the world. Technical assistance programs which involve institution building usually state or imply that assistance is being given to form a Land-Grant type institution. Such a descriptive term is intended to distinguish these institutions from the traditional European institutions that serve agriculture. Therefore, it becomes important, to identify clearly the distinguishing characteristics of a Land-Grant type institution.

Agricultural Development in Punjab; Retrospect & Prospects

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Agriculture is the pivot of the economy of the State of Punjab. Majority of its population (77 per cent) lives in villages, who directly or indirectly depend upon agriculture as a source of livelihood. Of the five million hectares of total geographical area of the State, 3.86 million hectares is cultivated. The total cropped area works out to be 5.1 million hectares giving an intensity of cropping at 131 per cent. The net irrigated area stands at 2.1 million hectares of which 0.88 million hectares is irrigated through wells and tube-wells. Most of the land in the State is, however, fit for growing at least two crops a year. Although there is not much scope for further extension of the area in the physical sense, it is possible to increase the intensity of cropping on the assured irrigation areas. The potential exists for achieving at least 200 per cent cropping intensity on an overall basis.

So far the increases in production have been coming mainly through increase in acreage under different crops. Comparing the food grain production in the State during the period 1951-52 to 1964-65, around 46 per cent increase in additional food production came through extension in acreage, 34 per cent through changes in cropping patterns and only a little over 17 per cent was contributed by the increase in yields. There is, however, a great scope to increase the yields further.

A study of the progress made during the period under review indicates that the production of wheat, gram, rice, maize and sugarcane, groundnut, American cotton and

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Considering the total value productivity of food crops in the State there has been an increase of 60.34 per cent in the year 1962-63 over the year 1950-51 giving a compound growth rate of 4.4 per cent.

There have occurred very encouraging changes in the land use patterns also. The total land available for cultivation has been increasing at a rate of 0.69 per cent per annum during the period 1950-51 through 1965-66 and the culturable waste, excluding the fallow lands, has been decreasing at a rate of 6.9 per cent per annum. Even the area under fallow has been decreasing at a rate of 7.15 per cent. Net area sown for this period increased at a compound rate of 1.07 per cent while the area sown more than once increased at a rate of 4.65 per cent giving an increase in the total cropped area at a rate of 1.85 per cent per annum. Intensity of cropping during this period has been increasing at 0.88 per cent.

Future Directions : Although agriculture in the State has developed at a very fast rate, yet keeping in view the needs of the society for food, fibre and other raw materials and also the production potentials of the State, there is a need to intensify the programmes aimed at agricultural development. Emphasis may be placed on the following aspects :

Irrigation : There is quite a scope of expanding irrigation facilities in the State, especially through pumping sets and tube-wells. With the construction of the Bhakhra Dam canal system, the water table in the State has come nearer the surface and in certain areas even the water-logging problems are being faced. Subsoil water is, thus, sufficient to support tube-wells of any capacity in the central plains of Punjab. We already have had an elaborate programme of installing pumping sets and tube-wells. During the year 1966-67, for example, Rs. 151 crores were provided for sinking of the tube-wells in the reorganized Punjab State alone, which brought 38,000 additional acres under irrigation and in the year 1967-68 around 10,000 tube-wells were energized against 11,000 during the year 1966-67. This year Rs. 3 crores were provided for minor irrigation schemes with a provision of Rs. 2.6 crores for advancing loans to the cultivators. This programme brougt about 63,000 acres under irrigation. Now that the commercial banks have entered

the field of agriculture, the situation of finances to help instal tube-wells and pumping sets can be expected to ease. It is expected that within few years whole of the area where irrigation is possible will be put under the command of tube-wells and pumping sets.

Soil Conservation : The soil conservation programme, particularly soil and water use management, is being given a very high priority in the State. During the year 1967-68 about Rs. 75 lakhs were spent on such programmes which covered an estimated area of 42,000 acres in the reorganized Punjab. Again, the water conservation is intimately linked with the minor irrigation work. It is estimated that under Punjab soil conditions, some 20 to 40 per cent water is lost by the time it reaches the place of its utilization. This means that for every Rs. 100 spent by the cultivator he gets a benefit of only Rs. 60 to 80. In view of this, a comprehensive programme to build *pacca* channels is envisaged. At some places underground water channels are also being laid out not only to save the water but also to save the land which would otherwise be covered by water channels.

Seeds and fertilizers : Fertilizer consumption in the State has increased a great deal. During the first five year plan period only 97.7 thousand metric tons of fertilizers were used. This figure rose to 1926.7 thousand metric tons during the third plan. In the year 1966-67, some 22.5 thousand tons of fertilizers were in the reorganized Punjab State alone, and in the year 1967-68 this consumption increased to 76 thousand tons in terms of CAN and Superphosphate. As the fertilizer programmes are expanded further with the adoption of high-yielding crop varieties, it is expected that their consumption would increase a great deal in the years to come. One major factor contributing towards their increase in fertilizer consumption has been the availability of credit facilities for this purpose to the extent demanded by the cultivators. In fact the demand for fertilizers has not been fully met and the shortages that occurred by the end of third five year plan are well-known. With the additional fertilizer production and imports into the country the situation is, however, easing quickly.

In respect of improved seeds, there occurred a break-through in some crops. Punjab wheat varieties stand

completely revolutionized these days and over 95 per cent of the irrigated area has been put under Mexican wheats this year (1968-69). The adoption of high-yielding varieties has been the major contributing factor towards increased production of wheat which went up by 50 per cent during the year 1967-68 as compared to the average of last three years. This production is expected to increase further by 20 per cent during the year 1968-69. Similarly, the progress made in respect of hybrid maize, paddy and *bajra* is also encouraging. During the year 1966-67 about 45,000 acres were put under hybrid maize, 11,000 acres under paddy T.N.1, 1,400 acres under *bajra*. We are, however, still in a transitional stage. The new heavy yielding varieties of wheat are expected to be in the field very shortly. Emphasis has also been laid on improvement work in hybrid and composite maize varieties such as Ganga 101, Ganga 103 and Vijay. With the improvement in varieties of the different crops and adequate supply of their seeds, it is expected that the production of various agricultural commodities in the State would shoot high within a few years to come.

In addition to these programmes there are specific developmental programmes aimed at increasing the production of commodities such as long staple cotton, sugarcane, and for popularizing plant protection measures and improved agricultural implements, etc. which are expected to go a long way in modernising Indian agriculture. Efforts are also aimed at the development of fruits and vegetables and increasing the production of milk and poultry products. These programmes are envisaged with a view to meeting the enhanced demand for the protective foods as a consequence of increased incomes accruing to the rural people of the State.

The direction seems to have been set, but the pace of these developmental efforts need to be accelerated and incentives need to be created for the farmers in respect of favourable factor-product price relationships so that investment on the farms is encouraged. It is only with these measures that agricultural growth in the State will keep pace with the changing situation so as to have a favourable impact on the rest of the economy.

Aspects of Agricultural Administration

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Our technical experts and arm-chair statisticians sometimes make an assumption that the economic development of the under-developed countries of the world requires only the technical know-how, more capital, and better trained men in larger numbers and that if these factors are forthcoming in adequate proportions, the problem of development is automatically solved. Obviously, such technicians are apt to ignore the role of human factor in the development process of a nation. As they are used to mathematical precision, they are prone to believe that the economic growth of a nation, like the growth of a plant is a function of certain factors of production, which if applied to the economy in certain proportions are likely to produce the desired results. I am afraid the problems of economic development are not so simple as that. In fact, man is a very complex being, who more often than not is moved by hopes and fears and is influenced by moods, emotions, his social environments and even by his eccentricities and idiosyncrasies while making decisions regarding the use of factors of production. For instance, it would be wrong to assume that if a country creates conditions for the production of a certain quantity of fertilisers, seeds of improved varieties, insecticides, pesticides and farm implements, the problem of agricultural production will be automatically solved. It has to be borne in mind that all these inputs that we produce have to be made use of by millions of poverty stricken and illiterate farmers, who have to make decisions regarding their use individually according to the social, economic and financial circumstances in which they live. These farmers have their prejudices and whims and even inhibitions which may not permit them to make use of these inputs for achieving higher production

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targets on their farms. Even if these inputs are acceptable and their supplies are assured, the financial position of some farmers may not permit their application to certain fields. Lack of education may stand in the way of the acceptance of modern techniques of production. It is, therefore, necessary for a country to create conditions in which the required inputs for higher agricultural production are not only produced, but are made available to the farmers in the right quantities and at the right time and are also made acceptable to them through proper education with the help of the Extension staff. A country which ignores the efficient management of supplies and popular education through the Extension agency will be doing so at its own peril. It is also necessary for that country to simultaneously provide for an equitable system of distribution in which each farmer is assured of the fruits of his labour.

2. There is also a futile controversy raging in this country between the technical personnel and the civil services. It is sometimes wrongly presumed that in this age of specialisation, technical men should also man all administrative positions and that both in the public and private sectors, the role of the general administrator ought to be very insignificant. This argument some times appeals to those unaware of the complexities and intricacies of administration. As I have already stated, the problem of economic development is not only a technical problem, but is also an administrative one. A person who has specialised in a particular technical subject may not always succeed as an administrator on account of the lack of experience in handling human problems and in such a situation, it becomes necessary for those who are guiding the destinies of a nation to find suitable persons trained in the difficult art of civil administration to man the key posts. In fact, like any other specialised art, administration also requires a particular kind of training and experience without which it may be difficult to maintain a social order with a minimum level of administrative efficiency, social justice and equality which are conducive to economic development. The policy of preserving the talent of the technical men for the technical field alone and of allocating the administrative work to the persons belonging to civil services, is to my mind very sound and helpful not only in the under-developed countries, but even in an economically advanced and progressive country.

3. You will now ask me about the special functions that a general administrator has to perform in a country undertaking the process of economic development. As I have already stated without administrative efficiency it is idle and futile to expect men and women to work efficiently for the economic advancement of the society. The following are the functions that an efficient system of administration has to perform before we can expect favourable conditions for economic progress :

(i) Maintenance of law and order in protecting life and property from external attacks, internal disorder, revolutionary legislation and eccentric State action. Without the maintenance of law and order, it is rather impossible to expect people to invest money in any public or private enterprise. Investment must be saved and protected from all risks and uncertainties inherent in a country where administration is indifferent or where a Government cannot ensure the saftey of life and property.

(ii) You will agree that different plans have to be prepared for the development of all the sectors of economy and priorities of development have to be fixed between different departments in both the private as well as public sectors so as to allocate the limited resources of a country between industry, agriculture, social services, public health and education in the best possible manner so as to ensure that excess capacities both in agriculture and industry are fully made use of. Whereas this will ensure the optimum use of machinery and industrial plants, it will also mean planning for bringing more land under cultivation by providing irrigation facilities and inducing farmers to adopt intensive cultivation methods by putting in more chemical fertilisers, better seed, pesticides, insecticides and improved techniques of agricultural production.

(iii) Framing of laws, rules and regulations and by-laws, ensuring justice and equality to different citizens before law.

(iv) Training young men and women of the country to take up responsible posts requiring special skill and ability for the development of the country in

different fields.

(v) Determining a satisfactory system of distribution of wealth so as to ensure everyone fair return of his labour.

(vi) To evolve simplified procedures and methods of working both in the offices and field and delegation of powers and decentralisation of authority in order to ensure the elimination of delays and quick disposal of work.

(vii) To execute the schemes and plans according to the priorities fixed by the planning agencies at different levels.

(viii) To ensure speedy and expeditious implementation of social and economic policies evolved at the national/state level.

(ix) To determine the conditions of work for individuals working in the public and private sectors, to determine their pay structure and to handle human beings working in different sectors of the economy so as to keep them happy and contented and to provide sufficient incentives to others to work hard *and to create conditions for good work in all* spheres of economy.

(x) To solve labour problems, frame labour laws and to regulate the conditions of work of labourers in public and private undertakings.

(xi) To decide which sectors of economy should invite State enterprise directly or through corporation and which sectors should be left untouched with private enterprise subject to sufficient, but not excessive State control.

(xii) To determine the commodities that the country has to import from outside and the commodities which she should export to foreign countries in order to earn adequate foreign exchange and to manage the factors of production in such a manner that excess unused capacity is avoided both in *agricultural and industrial sectors of economy.*

(xiii) To arrange for adequate and timely credit in the form of both short term and long term loans by building up an efficient and competent banking system in the country.

(xiv) To ensure the correct accounting and auditing of public expenditure.

4. We shall now see how administrative efficiency is important in our strategy for the agricultural development of the country. We all know that the development of agriculture in India is of supreme importance because it can vitalise and strengthen our economy by increasing the gross national out-put, by supplying food to our teeming millions and raw material for our industry and by providing the economic surplus which may be invested in the form of capital for future progress. In spite of all this importance of agricultural development, we find that there are a number of serious inhibiting factors which tend to hold up the agricultural development of our country. Unfortunately, a sort of quasi-equilibrium has been created in the field of agriculture on a very low level of production. The low income from land leads to low savings and investment and kills the spirit of enterprise and initiative that a farmer may otherwise possess. He is unable to provide himself with better quality seed, adequate quantities of chemical fertilisers and healthy and good animals to enable him to increase the out-put of the soil that he tills. The non-application of these inputs again leads to low production. This is an inter-locking vicious circle from which the farmer finds himself unable to get out. The State has to take steps to break these vicious circles somewhere so as to lift the economy to a higher plane and to jump on to higher and higher equilibria after attaining the 'take-off' stage. This is possible only if we provide for larger investment of capital in agriculture, intensive use of traditional techniques and application of the improved methods of production. Once the 'take off' stage has been reached and improved techniques of cultivation of land are adopted by our farmers, an ever expanding horizon for agricultural development will be automatically opened up.

5. The modern State is essentially a welfare State committed to promote the economic well-being of its citizens. The policy of free enterprise or *laissez-faire* advocated by the classical economists is dead and buried and there is hardly any State in the world including the U.S.A. where even lip sympathy is now paid to that doctrine, where public enterprise does not play a dominant role in the production of wealth and where the State does not control private business and industry to a very large extent. In these circumstances, when a State has to play such an important role in guiding the destinies of its citizens, it becomes necessary that the

organs of administration in the State should be strong enough and should be capable of handling the gigantic task of economic development in an efficient and just manner. The State has functioned extremely well in our country in executing the plans and policies laid down in the first three Five-Year Plans, but all of you know that there have been shortcomings and failures in implementing certain important policies. For example, in the 1st and 2nd Five-Year Plans, basic recommendations were made to protect the security of land tenure, to introduce agricultural reforms so as to give land to the actual tillers of the soil, to create conditions for the timely agricultural credits to the farmers and to stabilise agricultural prices. Unfortunately, these recommendations so necessary for the development sector of the economy have not yet been fully implemented. Another example that can be given of the gap between policies and the implementation is that of the provision of improved varieties of seed to the farmers. Even in an agricultural advanced State like Punjab, it has been estimated that traditionally only 3 per cent of the farmers get improved quality seed from the Government Co-operative agencies. Other farmers get some improved seed, but through the method of natural spread i.e., buying improved seed from other farmers. However, with the introduction of high-yielding varieties of wheat, rice and maize there has been a phenomenal increase in this regard. Apparently the motive of profits has played an important role. In spite of all the protestations and plans, it has been difficult to arrange supplies of adequate quantities of chemical fertilisers at the doorstep of the farmer. These are administrative failures indicating inefficient organisation and lack of proper management. Under these circumstances, even the best technical advice fails. What we require in the country is strong and efficient administration to arrange for the supply of these inputs to the farmers at the right time.

6. Efficient administration is also necessary to provide the farmers with an agrarian structure conducive to efficiency, to supply them adequate credit both long term and short term for adopting improved methods of cultivation and for making the investment required for achieving high levels of production, to ensure fair prices for agricultural produce and adequate marketing facilities. In addition to all this, we have also to provide for adequate Extension staff in order to ensure better contact between technical experts and the

farmers. Intensive agricultural research is no doubt necessary for the solution of problems posed by the farmers, but Extension workers are also required in very large numbers to disseminate the results of the laboratories amongst the farmers working in the field.

7. Another step necessary for the agrarian development in our country is to provide for geographical specialisation of crops and to follow the policy of land utilisation in order to maximise the agricultural production as a whole. Moreover, large scale, medium and small scale industries must be built up in order to lessen the pressure of population on land and for doing so we must try to tap our power resources to the maximum possible extent. The development of agro-based industries can provide work to the unemployed people and can also help in providing fuller employment to the farmer, thus increasing his income and leading to a higher standard of living in the countryside.

8. In addition to all the steps that have been mentioned before, we must not lose sight of an important condition necessary for the economic advancement of people. It must be borne in mind that no nation can progress unless a desire has been created amongst its people to have a better standard of living and unless leadership is available to them to provide the necessary guidance, for improving their standard of living. An example of what I have stated is provided by the farmers of the Punjab State and of the Kaira District in the Gujarat State where a desire on the part of farmers to improve their living standards has almost resulted in a revolution in the adoption of modern agricultural techniques by the farmers. The Punjab farmer has taken to mechanised farming and is prepared to spend money for improved seed, for chemical fertilizers and for insecticides. He is also prepared to listen to the advice tendered by the agricultural scientists once he is convinced of the utility of new ideas. Sometimes he is even prepared to take risks. The result is that the Punjab farmer is prosperous and has a better standard of living than the farmer of any other State in India. Similarly, in the Kaira District of the Gujarat State, farmers have adopted improved techniques of agricultural production and have developed a dairy industry which has surpassed all expectations of our economic planners. They have given up subsistence economy and have

taken to commercial farming. They are ready to migrate to other areas and even to go abroad and to show enterprise. Their sons not needed in the village go in for trade and even take to dairy farming. I quote from zinkin (Challenges in India) :

> "The Kaira District Cooperative Milk Producers' Union (to give it its full name) is claimed to be the largest in the world. Its dairy had just been rated the best in Asia by the Food and Agricultural Organisation in Rome. The Cooperative had 40,000 primary members in addition to its sixty founder members; it serviced 138 member societies scattered over 1,200 square miles. The share capital was £ 1½ million. More important, however, is that the Union had brought prosperity to the countryside. The 40,000 members owned between them 60,000 water buffalo cows. The average milk yield of these beautifully ugly beasts was low—250 lbs., a year, but it had an 8 per cent fat content against the 5 per cent of a good Western cow".

9. It has been estimated by Shri J. S. Patel in his brilliant book—'The India We Want' that in order to make India self-sufficient in foodgrains and to take the economy to the 'take off' stage, it would be necessary for us to raise the per capita agricultural output 2.2 times over the next about 40 years. This will mean about five-fold expansion of the total agricultural output with an annual growth rate of 3.4 per cent. With this rate of development, all our poverty, malnutrition and starvation can be knocked out once for all. Some people think that these targets are imaginary and are impossible of achievement. I am sure the fears of these people are unfounded; the targets are not at all imaginary if we take into account the fact that during the 3rd Five Year Plan period, we had aimed at an annual growth rate of 5.5 per cent per year and that the Ford Foundation which had surveyed the economic problems of India, had suggested an annual growth rate as high as 8 per cent for cereals. The out-put of foodgrains has to increase three to four folds in order to feed the growing population of the country and other sectors such as dairy and other products of animal husbandry, fish, vegetables, oilseeds, sugarcane and agricultural raw materials required for our industry. Given an efficient

and just administrative system and proper management of our economic resources, I am sure these targets can be achieved.

10. Before stating how these targets can be achieved, it is necessary for us to note the following salient features :

(i) The gross cultivated area in the country comes to a little over 150 million hectares of which about 14 million are cropped more than once and 3/4th of our cultivated area is used for growing food-grains.

(ii) The ratio of land cultivated per head (land-man ratio) comes to .37 hectares which is less than the world average of .47. This should not make us very dis-heartened if we remember that the land-man ratio in Europe (excluding U.S.S.R.) is only .35, in China .18, in Taiwan, South Korea and North Vietnam only .08 and in Japan .06. This means that we are not yet suffering from a very acute land shortage.

(iii) About 28 million hectares or about 1/5th of our total area under cultivation is irrigated. In addition to that, 30-40 million hectares of land in India have an assured rainfall. Thus, about one-half of our total cultivated area does not have any serious problem of irrigation.

(iv) The yield per acre of land in this country is extremely low as compared to the yield per acre of other progressive countries. About 75 per cent of our farmers with fairly average soil, produce only 85 million tons of cereals. This means we are producing only 9 quintals of cereals per hectare of land. The yields are about three times higher in Europe, South Korea and Malaya, 4 to 5 times higher in Egypt, Taiwan and Japan. This shows that the real trouble with our land is not that it is in short supply, but that on account of inefficient cultivation, we have an increditably low level of yield per unit area. We have millions of acres of land growing only one-half, one-third or even one-fourth of their potential. This excess capacity in agriculture has to be made us of, if we want to make ourselves self-sufficient in agricultural produce.

This excess capacity gives us hope that by the application of biological sciences to agriculture, we shall one day be able to produce much greater quantities of foodgrains than what we are producing now and that the ghost of Malthus need not haunt us in our dreams for the present. The potential contribution that our agriculture can make to the overall economic growth is indeed tremendous.

(v) Another important characteristic showing the state of our agriculture is its technical backwardness involving the use of poor seeds, inadequate weeding, absence of proper fertiliser in-puts, poor insect control and improper storage.

(vi) I have also to mention here a significant fact that the marketed surplus of foodgrains in India is about 1/3rd of the total output and only 15 out of 355 districts are reported to produce nearly 1/3rd of our marketable surplus. If all the 355 districts of India begin producing a surplus of marketable supplies including foodgrains, all our deficits in agricultural commodities can be knocked out in a period of less than five years.

1. It is sometimes believed that India being an ancient country without any virgin lands and without any colonies where our surplus population can be accommodated, cannot advance its economy to the same level to which the countries of Western Eurpoe were able to advance during the 19th century on account of the opening of foreign markets for their industrial goods and availability of virgin lands of America and Australia where their population could migrate and exploit virgin lands. It is no doubt true that in the 19th century, extensive cultivation of newly discovered lands and development of trade with countries producing the primary good and raw materials for their industries played a strategic role in the economic growth of the Western Europe. In the latter half of the 20th century, it is not extensive cultivation but intensive cultivation of land which offers immense potentiality and the most powerful tool to the Planners in the under-developed countries. No doubt, the area under irrigation can be increased, fallow lands brought under cultivation, the land unfit for cultivation reclaimed by soil conservation and other techniques and less fertile lands made

more productive, but along with these techniques of extensive cultivation, the more intensive use of chemical fertilisers, the use of seed of improved varieties and improved farming practices can surely help us in increasing our agricultural produce three to four times its present level. As the land-man ratio is almost the same in India as in Europe, there is no reason why Europe should be able to produce two and half times more than what India produces. We have not yet mastered the techniques of intensive cultivation of land. I give here one example only :

Whereas India uses only 3.5 kilograms of plant nutrient or needed chemical fertilisers per hectare and that also mostly concentrated on gardening and commercial crops, European farmers use 85 kilograms of chemical fertilisers per hectare. Similarly, the Egyptian farmers use 74 kilograms, the Taiwan 190 kilograms and the Japanese 310 kilograms of the plant nutrient per hectare and it is no wonder that Egypt produces four and a half times of agricultural produce, Taiwan five and half times and Japan nearly ten times as much as India.

12. The position regarding the use of better quality seed, moisture conservation, water use and other modern techniques of production is equally unsatisfactory. Our farmers do not make a significant progress in this direction on account of the lack of enterprise, financial resources and proper education. We must try to improve these conditions by removing these inhibiting factors from the life of our farmers, but it must be borne in mind that we cannot wait for a long time. Something has got to be done and very quickly if we have to catch up with the other progressive countries. If farmers are unable to apply the required inputs to land due to lack of financial resources or if they are unwilling to adopt the modern techniques on account of the lack of education and other prejudices, we shall have to use some sort of compulsion and all inducements to help them apply these inputs. Through our Extension agency we must ensure that agricultural inputs are used by farmers irrespective of their financial position or prejudices. Some sort of socialisation of agricultural inputs is very necessary to achieve this goal.

13. If we want to be as progressive as Egypt, Japan, Taiwan and Western Europe, it will be necessary for us to arrange for the required quantities of agricultural inputs

specially of chemical fertilizers and for doing this, we shall require not only the services of agricultural scientists and technicians, but of capable administrators who can plan for the production of the required quantities of chemical fertilizers and also provide for stabilisation of farm prices, expansion of marketing and credit facilities on cooperative lines, provide for adequate incentives, guaranteed tenure of land on fair rent and the popularisation and distribution of necessary inputs.

14. All this requires an efficient system of administration and ability to organise things for which good administrators will be needed by this country in thousands. Thus, the controversy between the technician and the administrator in this country is rather futile and is based on misunderstanding. What we need is cooperation between the technical man and the administrator so that the economic development of this country is achieved in a reasonably short period by their joint efforts.

Chapter II

Agricultural Universities in India—Some lessons

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At the Punjab Agricultural University, Ludhiana, we are celebrating the early success of one of India's more important institutional innovations of the past ten years, and I propose to dwell for a few minutes on a few of the lessons that can be drawn from the experience.

Lesson number one is that rapid and successful economic development does indeed depend on more than sheer quantitative increments of capital, foreign exchange, imports, and domestic resources. It also requires the creation and development of some new institutions. Fifteen years ago in India there were many antecedents of what has become the new agricultural university, but there was nothing quite like it. Indeed there was nothing at all like it, if you view the agricultural university in the round as the inter-acting, inter-penetrating complex of teaching and short-term training, of research, and of direct service to cultivators that has so clearly emerged here in the Punjab. In concept, therefore, as well as in scope and importance the new agricultural university is indeed brand new; and, it already is making formidable contributions to the nation's progress.

A second lession is that, just as one can borrow technologies

*Adapted from the address presented by Dr. John P. Lewis, Minister-Director, U.S.AID, India, on the occasion of the Special Convocation of the Ohio State University at the Punjab Agricultural University, Ludhiana, to Confer an Honorary Degree on Dr. P. N. Thapar, on March 15, 1969.

from abroad in support of the development process, so the ideas for the new developmental institutions can be gathered from a variety of sources. Designers of institutional change have access to a whole array of models that come from many countries and from a considerable range of recent history. In the present case the idea of the new Indian agricultural university draws in part upon the model of the American land-grant university. America, herself, of course, imported the idea of the college from Britain and the idea of the modern university from Britain and Germany. But the service-oriented land-grant university that combines education, research, and extension in one integrated package is an American mutation. And now that mutation, with further modifications, has been imported into India. That it seems to fit and work is, of course, a source of great statisfaction to Americans.

But, having asserted this importability of some institutional innovations, one must move on at once to a third lesson, which may be the most important. It is that the most vital as well as the largest inputs, whether of design or of implementation, into any successful institutional innovation must be indigenous. Wherever its seminal ideas come from, there must be a place and a need for the new institution in the local environment, and it must more or less fit a gap in the fabric of existing institutions. It must, that is to say, fit into the fabric with no more than a reasonable amount of stretching—it seldom can succeed while tearing the existing fabric as under.

This question of the potential adaptability of a new institutional idea to local needs and circumstances is a hard one for outsiders to judge in advance. Certain other attempts at institutional importation into India during the past fifteen years have not worked nearly as well as the agricultural university. Much of the credit for success of the latter must go to those Indian adaptive designers who saw the opportunity and need for institutional innovation, who recognized the adoptive and adaptive potentialities of the land-grant university concept, and who then set about making the initial modifications in the design and doing the necessary job of selling the hybrid Indian-*cum*-imported innovation to the governments and parliaments in the States and New Delhi.

By a happy circumstance, one of these very progenitors of the Indian agricultural university is sitting on this platform this morning in the person of Punjab Agricultural University's *new* Vice-Chancellor, Dr. M. S. Randhawa, who recently has come to take charge of an institution that, as a senior official, he played a key role in initiating. But I am sure that Dr. Randhawa would join me in saying that, while design and planning are important, implementation—especially the initial implementation of the scheme for a new institution—is crucial. And this, of course, is where the first faculties and the first administrators of these new institutions, among whom Dr. P. N. Thapar has been outstanding, played the decisive role.

Outside assistance—in the Punjab case from the Ohio State University, backstopped by AID—can continue for a time to be very useful It can help catalyze the whole undertaking, and it can provide a variety of suggestions and advice and of overseas training that can be most helpful at the margin. But the burden and thrust of the effort must be unmistakeably Indian.

On this general point of the interaction of external and internal inputs, agricultural universities, in short, remind me of the high-yielding variety wheats you here in Ludhiana District know so well. Many people abroad, and, indeed many Indians, still are talking about what wonders so-called "Mexican wheat" has been working in India these past three years. The so-called "Mexican wheat" stems from a breakthrough in biological technology that originated in Japan and was pursued and developed in Mexico under American auspices; and Americans, especially of the Rockefeller Foundation, helped a good deal in building readiness for and interest in its introduction here.

But much of the preparation was the work of Indian plant breeders and the organizers of Indian agricultural research. The massive introduction of Mexican wheats was effected by a bold risk-taking decision of the Government of India to introduce them in quantity in the spring of 1966. And the indigenous implementation and adaptive-research phase of the effort already has made such progress—for example, at this very institution—that "Mexican" wheat in its original form already is almost a thing of the past.

The fourth lesson I draw from the coming of age of the Indian agricultural university has to do with the pace of institution building that is possible when the conditions are right. When the ground is fertile and prepared, when there is a pressure of need to galvanize decision making, and when the experience of others (albeit adapted to local circumstances) is exploited shrewdly to short circuit many of the mistakes and delays that have been incurred elsewhere—then, under these circumstances in a developing country like India, successful institution-building can proceed at a relatively phenomenal speed.

In the United States the Morrill Act providing for the establishment of land-grant teaching institutions was passed in 1862. The Hatch Act providing Federal support for agricultural research activities and experiment stations in these land-grant colleges was passed 25 years later, in 1887). And the Smith-Lever Act, adding support for the extension activities of the same institution, did not come until 1914. Thus it took more than 50 years even to get the necessary legislative underpinnings for the modern land-grant university.

The host institution at this convocation—Ohio State University—was chartered as a college of agricultural and mechanical arts in 1870. It did not get started until 1873. By 1878, although it had been re-named, it was barely launched as a significant institution. And few, if any, of our American land-grant universities, even in our newer states, got off to faster starts.

By comparison the pace of this agricultural university—and indeed, most of the Indian agricultural universities—has been remarkable. In the space of four to eight years they have become not only major undergraduate and graduate teaching institutions but in most cases leading centers of focused, relevant, and applied agricultural research. And, although the degree to which they have been granted extension functions varies from state to state, most of them are reaching out extensively into the here-and-now agriculture of their states with an array of information and services. Already they have become, not just theoretical or potential centres, but actual major operating centers of the Green Revolution that is now underway.

growing shares of the planning, decision making, and financial responsibilities for development.

In the second place, I see institutions like this one becoming increasingly influential because of their agricultural focus and the fact that in most Indian states agriculture is due to remain at the centre of the economic stage for some time to come. By the same token, the progressive, modernized agriculture with which these universities are concerned will increasingly impinge upon activities that, in a narrow sense, are non-agricultural—upon input and supplier industries, irrigation engineering, the adequacy of rural infrastructure, the processing of agricultural products, all of the marketing organizations and institutions that will become engaged in distributing farm products—and indeed, upon the whole shape and texture of life in the countryside : in the villages and the towns around which agriculture-related activities will increasingly cluster and develop. Thus, even though I hope they show a good bit of self-restraint in order not to dilute their primary agricultural mission too early, universities like this one will be drawn into more and more complex and diverse involvements.

In the third place I see agricultural universities as exciting and involved places in the years ahead simply because they are universities. Universities always have been (or at least always should have been) crucibles of change, conceptually speaking. But in the past they have often had a detached, arms-length relationship to the hurly-burly of ongoing life around them. All over the world now this detachment of the universities is disappearing, often in a puzzling, tumultous manner. But basically this increasing engagement of the universities in the real world, this insistence of students upon pulling the turmoil and problems and excitement of the world into the campus seems to me a healthy thing.

And that brings me to the final reason why I feel so sure this particular kind of university is due to be broadly and deeply engaged in the whole life of its state. This is because of its particular and different character—one that is dedicated, more explicitly and directly than is the traditional university, to a role of current service, of applied research and of direct interchange with a broad segment of the adult community.

The agricultural university, borrowing in part from the land grant university model, has broken out of the old models. Its service orientation and its inherent commitment to innovation, will, I hope, give it two operating characteristics as it now matures. First, as it interacts with its constituency outside the campus it will remain alert to the continuing needs for innovation—both technical innovation and social innovation in organizational arrangements that increasingly engage the farmers, villagers, and the town people of a state like the Punjab in the business of managing their own public as well as private affairs.

Second, the innovational bent of these universities should give them a special talent for keeping their students constructively engaged—for one thing, because what the students are studying and doing is so manifestly relevant to the problems of the real world, and for another, because the agricultural universities will continue to pioneer in new ideas of student involvement and of student-faculty relations that accord students a growing partnership in the conduct of their own programs.

Basic Concepts in Higher Teaching

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Search for truth along the path of reason leads to knowledge (Jnan). The process of course is dynamic, since every step trod on this path opens up new vistas and horizons in the fathomless ocean of knowledge and these become the future objects of enquiry.

A curious and ardent enquirer standing at the last leg of journey establishes a link between the past and the present in the form of a teacher and his student. A good teacher to a student like Plato is, as described by Newman "a stay for his mind to rest, or a burning thought in his heart, a bond of union with men like himself, ever after".

A successful teacher leads the student to shape himself in a manner that the student goes on the path of knowledge even when he would not be there. Creative education must give self-fulfilment of the curiosities, and encouragement for further indulgence in pursuit of difficult problems, and with every effort the seeker must attain more and more perfection.

To achieve this, the first essential, is that the teacher must know the subject and he must continue to learn it, because no one at one time knows all that is to be known. The difference between the teacher and the taught is of the stage, and both of them have the same purpose, and each of them learns with the other. The student continues, where teacher leaves.

The second essential is that the teacher must like to share

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what he knows, and should derive a sense of satisfaction from successful transmission and communication of his thoughts, by which knowledge grows further. In absence of such an urge, many arts and techniques well-developed in ancient India ended in a blind alley and died with the man.

Communication, the transmission of thought, from one mind to others, is one of the basic activities of the human race and teaching depends upon it. It is an art without which a genius is dumb and if done effectively, make men a magnificent success. There are two main methods of communicating knowledge. First is lecturing. University lectures are mostly of this type. The second method in the modern education was invented by Socrates and can be called the tutorial system. Here the teacher does not talk. He asks questions, and the pupil talks. The questions are so arranged as to make the pupil conscious of his own ignorance, and to guide him towards a deeper truth. It is important here that there should be some basis of discussion, so the pupil usually does some work in preparation, which his teacher then examines, critises and by constructive questioning attempts to deepen his knowledge. In essence, the system though credited to Socrates does not seem to be new to India, since the Rishis of the Upanishad period perfected and effectively used this system in transmitting and communicating the metaphysical aspects of life to their disciples.

Teaching in Greece during fifth century B.C. was dominated by the group of "Sophists". These were exclusively lecturers and usually faced large audiences. They delivered carefully prepared speeches which reflected their brilliance and artistry of oration. They were highly paid and widely advertised. The effect of their preachings and orations kept the audiences spell-bound but did not travel outside the meeting hall and, therefore, the thoughts from the teacher to the taught did not flow like a refreshing stream but culminated in a momentary elation followed by stagnation.

The tutorial system followed by Socrates lays more emphasis on the personal contact with the student by which knowledge of the past and ignorance of the present become explicit. The difference in the method of Sophists who depend on prepared speeches and of Socrates was that they claimed

the knowledge of everything, and thought the end of the knowledge was with them; whereas Socrates said he knew nothing and was trying to find out through the process of reason and logic, by which he trained people to think thereafter. So the Sophists were the first lecturers and Socrates was the first tutor.

The tutorial system which is based on cross examination can only be used effectively by the teachers who have some set of positive beliefs and facts from which questions flow. Random questioning does not develop the chain of thoughts by which brilliant students construct the next link, which comes out of the natural process of reasoning and implication. A direct explanation of facts sometimes goes unheard. That which stimulates pupils to think for themselves often has far more potent influence and gives the satisfaction and excitement of self achievement.

The present system of education is a synthesis of lecturing and tutorial system leading to discussion in which every step of the argument is exposed and conclusions drawn. With the advancement of knowledge at higher levels of education, lecturing seems to be less important than inductive questioning during an informal discussion. This encourages thinking along the lines suggested—not laid down, but suggested by the teacher. The arguments should not be a fight between the two persons but a hunt after reason in which both join, helping each other to detect and capture the truth being sought. Plato thought "there is no possible way to educate people, to convert them and change them and convince them fully and lastingly, except by calm, cool reasoning. Ask the questions, examine the answers. Go on discussing until the reason is satisfied with the result". This was probably the basis that turned out such a magnificent series of great men like Socrates, Plato and Aristotle.

Aristotle was the closest to modern university education in his approach, because he thought research and teaching as two sides of the same coin. "His Lyceum (name for the institutes) resembled a modern research institute. The vast numbers of specimens for his biological work which he collected from many parts of the known world must have been worked by squads of research students; and his masterly political treatises were the distillation of important analyses

of numerous existing constitutions made by his assistant under his supervision". He combined lecturing with class discussions but put the emphasis on the lecture.

Training of young scientists as the creative thinkers of tomorrow is a difficult task. In this process it is the teacher who is really important not the institute or the scientific equipment. Imposition of ones authority or supremacy in the subject matter may create disgust and revolt in young minds, since all the young hate authority and youth goes by the victum that "it is better to reign in hell than serve in heaven".

A modest declaration of one's ignorance encourages the other man and makes him eager to explain to his best what he knows and the satisfaction of ego stimulates interest in knowing more. Knowledge is intoxicating and an intoxicated man strives to get more and more of it. Morgan when asked about his brilliant students, Muller, Bridges and Sturtevant replied "Each one of us knew what was known by the other and discussed each others problems with equal fervour and enthusiasm". One can easily see the effect of such a method by which the discoveries of this school became the land-marks in the biological sciences.

A teacher, however, great he may be in his knowledge, in the words of Newton, "is only collecting people on the shore of a vast ocean of the unknown". He knows more and can plant better, but that knowledge he has acquired was not devoid of mistakes he committed in his early days. Telling these small mistakes to the students creates faith and confidence in the young mind who realizes that what has been attained by his teacher is not beyond his reach if he really works hard.

Many research workers and discoverers are not good teachers in the formal sense of the art of teaching; yet they are very effective in guiding their advanced pupils through research in the laboratory and seminars. The methods differ widely with the subject and individuals but invariably the quality possessed by all of them is "Intellectual honesty". In such cases, the personality and reputation of the teacher creates a lasting influence through personal relationship with the students. H. K. Hayes a leading plant breeder at the

University of Minnesota trained plant breeders with such remarkable success, that at one time, seventeen heads of the departments in the various North American Universities were the students of Dr. Hayes, a modest class-room teacher.

Training takes many shapes with the individuals. A professional scientist is a man who sees things which other people miss, so he must be trained to see things for himself. Simple things which are known facts with the teachers may be mysteries for the student, and their knowledge by self effort and search gives not only the satisfaction of knowing it, but also develops the habit of self enquiry.

One of the students of Dr. T. J. Arnason, on enquiring about the details of fixing and hydrolysing barley root tips, was told that he did not exactly know and that he should look in the literature and find out by trying various timings and chemicals. The student tried this on his own and after a week or so when successful, he went to Dr. Arnason in all his excitement and enthusiasm to report his findings but got a cool answer, "Yew I know". If he had been told at the first instance, the students would never have learned where to look for such things. Learning by self criticism till it is self-satisfying is the best way for progress, since no one knows one's weaknesses better than oneself.

University education in its present form was introduced by the British Government in this country and has all the over tones of the western concepts and thinking. However, organised higher education had attained very high standards at Nalanda and Takshshila during the Gupta period. These institutions drew students from far and wide, across the Indian frontiers. Personal contacts between the teacher and the taught and the dedicated and selfless life of the teacher were the life source of these institutions. In recent years teachers such as Dr. P. C. Ray and Sir C. V. Raman, through their ideal lives, drew admiration and helped to shape the destiny of the most talented students of their time like Dr. Krishnan the eminent Physist and Dr. N. R. Dhar a soil scientist. In the field of Botany, the students of Dr. Birbal Sahni had a permanent impact of deep humanism and devotion shown by him in his day-to-day dealings.

In recent years, however, University education has deteriorated to such an extent that our President, a distinguished teacher himself, was led to remark that "our education at the undergraduate and the graduate level is not turning out Indians". The reason is not difficult to find. This situation has arisen because the universities as stated by our Education Minister Dr. Triguna Sen are "preoccupied with the pursuit of statistics", of the number of students that pass rather with the pursuit of excellence.

Loss of contact between teacher and taught and dependence on the "cooked up recipe" for passing examinations in the form of solution papers and dictated class notes have maligned the creative potential and independent thought of young minds.

A successful teacher is one who does not put the blinds of his own ideas and thinking on the pupil's mind; rather he unveils the dark spots and develops the power of reasoning and criticism. The result of good teaching is summed up in the words of Aristotle who proclaimed "Though both truth and Plato are dear to me, it is right to prefer truth".

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The Art of Teaching

DR. PREM PRAKASH*

The art of teaching is the communication of ideas from one individual to another. Among the various ways of communicating ideas and facts to the masses, either for educating them or for creating a certain atmosphere among them for the desired change, a lecture, in the widest sense, is a very powerful and effective medium. Our world of modern technology and philosophy has changed the concept of a teacher on one end of a log and a student on the other. This change, however, is one of order and degree and not of principle. In our consideration of those teaching devices that we call teaching aids we must not forget the value of the blackboard and chalk, as a supplement to a well prepared lecture followed by an enthusiastic discussion. Through constant practice and effort toward improvement of presentations, many teachers have become superior teachers using free hand diagrams, charts and graphs to illustrate their subject-matter. Today the teacher finds himself faced with the problem of including more and more subject material in his course, often without a corresponding increase of time. The effective use of teaching aids can provide, at least, a partial solution to this problem. But we must always keep in mind that teaching aids are effective only when used by a skilled and informed teacher.

Haas and Packer define the teaching aid as a device that assists the teacher to transmit to a learner facts, skills, attitudes, knowledge, understanding and appreciation.

A visual aid is any instructional device that can be seen but not heard.

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An audio aid is any instructional device that can be heard but not seen.

An audio-visual aid is any instructional device that can be heard and seen.

Advantages of Audio-Visual Aids in Agricultural Education—

(i) They create interest in the agricultural programmes.

(ii) They put the message in a realistic background and thus make learning easier.

(iii) They reach many people at low cost.

(iv) Charts, models and films along with demonstrations can be used. For example, they will illustrate and elucidate problems like : "Physiology of Reproduction", "Role of Nutritional factors in Reproduction".

Important teaching aids : (i) Blackboard : One of the best of all teaching aids is the blackboard. Not only does every class-room have one, but all students are familiar with its use from an early age. One of the best ways of using the blackboard is to construct a list of the basic points of the lesson just as they emerge during the course of lesson. Alternatively a blackboard summary may be constructed at the end of the lesson while recapitulating the main essentials. Sometimes it is useful to have a summary on the blackboard before the lesson begins and students may show more understanding if they can see before-hand the gist of what they are going to hear.

Coloured chalk is useful for blackboard work, though it takes much washing off the hands. If there are questions on the board, writing the answers in colour distinguish them conveniently. A sketch-map or diagram on the blackboard is often valuable. It should be as simple as possible, and be drawn large with bold lines.

Care should be taken to ensure that the blackboard can be seen by all students, and is not in the glare of the sun or any electric light which can sometimes mean a blind spot somewhere in the class-room.

Before he leaves the class-room, the teacher should always clean the blackboard as a matter of courtesy to the next teacher taking the class. The principle here is that, if one

has been responsible for writing on the blackboard, one should also see that it is rubbed off. It is very irritating to have to begin a lesson by wiping the blackboard. Moreover, time can be saved if the clearing is done during the interval between lessons rather than at the beginning of a lesson.

(ii) *Maps, Charts, Graphs and Diagrams :* They have been named the "spark plugs" of visual training because they are easy to make and are effective devices for instruction. These teaching aids make dry and often meaningless facts more understandable and interesting. These can be displayed in the class-room for reference by the Instructor during his lecture and discussion and by students at their convenience. In teaching, one has frequently to make use of maps for illustrative purposes. The diagram is similar to the map in that it is a simplified representation of something. The essential qualities of a good diagram are that it is simple and free from unessential items, that it actually shows the features to which the attention of the students is to be drawn and that it can be readily seen and examined by all the students concerned.

Table charts are indispensable in many teaching situations. They are effective, for example, in presenting a breakdown of financial statements, such as the balance sheet or the profit and loss statement. They may also be used for comparisons or for listing advantages and disadvantages of a business or an organization.

Graphs are effective tools for making comparisons and contrasts or for presenting complicated facts to students. A long column of statistics looks impressive, but is usually skipped over. However, an interesting graph on the same figures will arrest attention and make students stop, look and think. A good graph requires little explanation and tells its story at a glance. Many instructional topics may be presented with the bar graph, the 'pie' graph, the line graph.

The bar graph consists of bars arranged horizontally or vertically from a zero base. Size, length or colour of the bars represent the different values. Bar graphs are easy to understand and are especially helpful in comparing or contrasting many subjects.

The pie graphs are especially helpful where a 'breakdown' or distribution of values is important such as the growth of various areas. Each section of the pie can be painted by using different colours and placing the percentage number in each one.

The line graph is commonly used in industry, agriculture and business and is helpful in depicting economics and business cycles and trends.

(iii) *Posters* : Generaly speaking there are five basic points that create a good poster : theme, presentation, wording, design and colour.

Posters are a simple graphic interpretation of the greatest possible impact. The majority of teaching posters are used to present the steps in a topic. Each step or idea in the poster is carefully presented to the student in proper order. Posters should be displayed in a conspicuous place in the front of the class-room. They provide a convenient and handy basis for the use of visual education in social work.

(iv) *Models, Objects and Specimens* : Of all the audio-visual materials, models, objects and specimens are replicas of the real thing. When it is physically impossible or impractical to use the real object in the class-room, a model or specimen will do the trick. In fact, these teaching aids are of powerful interest—arousing devices that possess the capacity of bringing into play all five senses—touch, sight, hearing, smell and taste. A dissected model of buffalo often shows the proof more clearly than blackboard illustration.

(v) *Flash Cards* : It is said that lightning never strikes twice in the same place, but instructors can strike repeatedly at the understanding of students by the use of flash cards.

Flash cards are small compact cards approximately 10×12" which are flashed before a class to bring home an idea. The message the cards contain is brief and to the point. The cards may also be used effectively in a drill or review. They may be used effectively in a large number of situations. By presenting a systematic set of flash cards, the steps in prevention of a disease or improved cultivation

practices, etc., can be reviewed so that they may not be forgotten.

Be sure to expose each card so that everyone of students can observe it. Review the topic by pointing to each step on the flash cards and have the group read it aloud. If the meetings are being held weekly, it is very hepful to refresh the minds of the students by presenting flash cards of the previous class before starting a new lesson.

(vi) *Flannel Boards :* The flannel board technique has become more important in recent years. A flannel board is a flannel-covered flat surface. Various objects such as pictures, magazines or newspaper cotouts, graphs, drawings, text materials, and other illustrations with similar rough flannel-like backing are placed on the board as the presentation is developed by the instructor. The objects placed on the board adhere to it, without the use of thumb tacks or scotch tape. This makes it possible to construct and develop an idea step-by-step in a very dramatic and impressive manner. Another outstanding feature of the flannel board presentation is its flexibility. Relevant topics can be chosen and then analysed in the form of serial stages. New materials may be added and outdated material deleted. Colour may be used to attract and focus attention.

(vii) *Bulletin Board :* Bulletin boards may be used to display numerous items, such as : bulletins, news items, announcements, subject outlines, drawings, graphs notices, pictures, pamphlets, and multifarious displays. Bulletin boards serve as the "show window" of your programme. A student's interest may be aroused by simply placing his name on the bulletin board, a chart showing his progress is even more effective. Another method for arousing interest in a topic is to arrange an interesting bulletin-board display several days prior to the introduction of new subject-matter. The display must have reader interest and sufficient time should be allotted so that the student has ample opportunity to observe it.

If the bulletin board is portable, place it in front of the class-room. It is also helpful to have the illustrations arranged on the bulletin board in the proper sequence, i.e., the order in which you will present the various steps to the class.

(viii) *Recordings and Playback Equipments in the Class-room :* Valuable lectures or radio programmes that are broadcast outside college hours may be recorded on discs, wire, or tape and played back in the class-room when needed. Instantaneous recording and playback equipment is also valuable for immediate class-room learning and consequently should be available for use by students and teachers in all scientific fields.

(ix) *Film Strips :* A film strips is made up of a series of still pictures arranged in a proper sequence to explain an idea or a process or to tell a story. Each strip contains from 25 to 100 pictures. The film strip can be projected on the screen for any length of time, by holding a frame on the screen. Students and instructor can then discuss the contents as exhaustively as may be required. They may also facilitate the comprehension of an idea or a process, step-by-step.

(x) *Films :* Films in agriculture and veterinary science provide the most dynamic and universal media of information. They show certain processes of the animal body that require motion. They overcome limitations of time and space. They are most effective when students have been told in the class what they are going to see. A topic covered in this way will make a deeper and more lasting impression than if it had been dealt with within the class by the usual methods.

(x) *Teaching Slides :* A few carefully selected slides or even one pertinent slide can attract attention, arouse interest, assist lesson development, test student understanding, review instructions and facilitated student-teacher participation.

The versatility, facility of selection, low lost and case of preparing slides makes them important teaching tools. The instructor can spare himself many sad experiences if he verifies the following items before the class meets :

1. Check each slide
2. Arrange slides in proper showing order
3. Set up projector and screen
4. Check seeting arrangements in room
5. Check lighting
6. Check ventilation
7. Test projector

Production of Teaching Aids : Whether he personally produces his teaching aids or has them produced by a professional craftsman, the teacher must know specifically and in detail what he wishes to present. He must be familiar with the scope and limitations of the medium he selects. He must have at least a general knowledge of that medium and the techniques involved.

An Effective Approach in Evaluating the Performance of Students

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Evaluation is an integral part of our everyday activities. For each job there is a goal. In education the goals are fixed on the basis of the students' needs. Educational programmes are established so that students can reach these goals in reasonably efficient manner. After the programme has begun, information such as tests, scores, and reports of observation of student behaviour is periodically gathered. The success of the educational programme is evaluated in terms of the objectives.

Purposes of Educational Evaluation : The purposes of evaluation are :

1. Educational evaluation helps the teacher to determine the degree to which educational objectives have been achieved.
2. Evaluation helps the teacher to know his students individually.

The first purpose is basic and the second is subsidiary to the first. If the teacher is intimately familiar with his students, he will be better able to determine the degree to which the educational objectives have been achieved. The task of the class-room teacher is to assist his pupils in reaching the general and specific goals of education.

Every Teacher must know his Pupils : He should begin by asking their names, addresses, previous education, address

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and the occupation of their parents. A teacher should be more than curious about the students aptitudes, the complete story of his previous achievements and the degree of his personal-social adjustment.

The procedures used in educational evaluation are varied. They include paper and ink test, ranking and grading scales, performance test, home assignments, quizzes and oral tests. The purpose of these and other methods is to provide information so that decisions can be made.

It is well-known that the measurement of individual ability, achievements and characteristics offers the most solid basis on which students may be assisted in the choice of studies and the occupation. Frequent examinations help the instructor to know how effective is his teaching. The teaching is more effective if the teacher prepares his lessons like a student. To be a good examiner, he must be a good teacher. I would suggest a few guide lines to good teaching :

(i) Be punctual : You should be near the lecture-room a minute before the scheduled time. For a laboratory course, you must be in the laboratory 15 minutes earlier and see that the necessary equipment apparatus and solutions are ready before the class comes in. Also check that there is proper arrangement of light and blackboard.

(ii) Be honest, self-reliant, enthusiastic, tactful, sincere, courteous, cooperative and well-dressed.

(iii) Have good poise and show initiative.

(iv) Keep breath that is not offensive and your body should have no bad odour.

(v) Talk, but do not shout.

(vi) Be interested and try to understand students' problems.

(vii) Answer all questions. Side step no issues.

(viii) Do not ridicule the students. Control your temper at all times.

(ix) Refrain from over-familiarity with students.

(x) Commend good work and attitude of students.

(xi) Keep abreast with latest literature.

(xii) Look upon teaching as an opportunity for service.

(xiii) Attend to college business at the campus and do not entertain guests for gossip.

(xiv) Do not make reference to politics and religion.

(xv) Keep on the subject, do not wander. Ask questions which are pertinent and thought provoking.

(xvi) Hold quizzes regularly every week; to correct weakness provide incentive.

(xvii) Refrain from securing favour for yourself at the expense of your associates. Do not make uncomplimentary remarks about others.

(xviii) Stay within communication channels with official matters.

(xix) See that the room is well-lighted, and ventilation and temperature are comfortable.

(xx) See that the students work for the entire period. Do not let them go before time.

As you move into this Trimester System, you broaden your concept of testing and use course achievement tests which will you in making the examination as a means rather than as an end in itself. Tests may be used in many ways. Among these are the following :

(1) The tests may be used to appraise the student of his personality in order that he may better understand himself and practice self direction.

(2) Tests may be used to give an accurate comparison of individual's performance with that of others.

(3) An imortant use of tests is the improvement of the basis of prediction of success, whether educational, occupational or professional.

(4) Tests when correctly used may assist in the evaluation of personal characteristics needed for success in a chosen field.

(5) Tests may, be used to evaluate achievement and growth, both for the individual and for the group.

(6) Tests may be further used to disclose the student's capacity and his potentiality as well as his disabilities and deficiencies.

Specific seminars could be held, using the following topics for discussion :

(1) Planning the tests.
(2) Writing the test items.
(3) Trying out the preliminary form of the test.
(4) Determining procedures and the preparation of instructions for administering and scoring the test.
(5) Reproducing the test and explanatory material.

Ultimately as you become more sophisticated in the use of measurement techniques you can move into the consideration of such topics as the reliability and validity of your test with the establishment of units scores and norms. You have moved from the External Examination System at the end of the course to the Internal Examination System with the individual professor being able and willing to assume responsibility for the establishment of the objectives in the course which he is teaching, the selection of the content and experiences which will best help the student in reaching desired goals, the determination of the effective organization of class experiences and finally the appraisal of the effect of these learning experiences on the student.

Examination and Marks : Under the Trimester System a number of examinations have been substituted for the end of the year examinations under the old system. In the new system the examination will be an integral part of the teaching process. The type of examination to be given will influence the students preparation for their examination. The various types of objective examinations are listed and described very briefly below :

Simple Memory Test : The examiner asks questions which can be answered with a word, phrase, principle, formula and so forth.

Recall Reasoning : In this instance the student is asked to recall certain information and then apply this information to a particular situation involving reasoning.

Completion : This is a variation of the simple memory test where the student is asked to apply certain missing information.

True, False : This is a widely used type of test which allows the uninformed students to obtain approximately 1/2 of the total as correct answers. Some provision then should be made for guessing.

Multiple Choice : In this test normally four or five best answers are suggested and the student must make choice of the correct answer.

Sequence : In this instance the student is asked to arrange the items in a prescribed or systematic way.

In the use of objective tests it is wise to give the student correct answers when the papers are returned or perhaps to ask the student to correct his own test papers. The student should not be left with the impression that his wrong answer is correct.

There are, of course, many modifications of the objective type examinations.

Suggestions for Short-Answer Form :

1. Use the question that can be answered by a phrase, number of word.
2. Do not borrow statements from context to use them as short answer item.
3. Make the question or the directions explicit.
4. Allow sufficient space for the answer and space for scoring.
5. Avoid over-multiplication of exercises.
6. e.g. A hay.........affords another..........of the existing..........between........and......

Suggestions for T.F. Form :

1. Base the true-false items only on statements which are true-false without qualifications.
2. Avoid the use of long and involved statements which may qualify phrases.

Multiple choice form

1. Use a direct question of an incomplete statement as the item stem.
2. If possible, avoid a negatively stated item stem.
3. Make all distractors plausible and attractive to the examinees.
4. Avoid highly technical distractors.
5. Avoid responses that overlap or include each other.
6. Use 'None of these' *as a response only in items to* which an absolute correct answer can be given.
7. Arrange the responses in logical order.
8. Do not present a collection of true-false statements as multiple choice items.
9. To deal with the definition of a term, it is preferable to include the term in the stem and alternative definitions in the responses.

Matching exercises

1. Group only homogeneous premises and homogeneous responses in a single matching item.
2. Use short lists of responses.
3. Arrangements should be such as to give maximum clarity.
4. The directions should clearly indicate the basis for matching.
5. Do not attempt to provide perfect one-to-one matching.

Suggestions for writing

1. Select the type of material to be interpreted for significance and representativeness.
2. Write or rewrite the material to be interpreted to eliminate non-functional portions.
3. Construct the items in multiple choice or true-false form with regard to all suggestions previously made.
4. Decide in advance how much emphasis should be placed on student's background *information*

and then construct question to get the decided emphasis.

Essay type examination : It measures direct approach to important goals, but thousands of students who answer subjective questions are not able to handle their papers efficiently. Sixty-seven thousand boys were given subjective tests in U.K. when 74 per cent of them failed. In fact the examiners want the students to be learned, witty, charming and show themselves equal to Addison, Johnson or even Shakespeare. The results have been worthless as measure of any ability of importance or dependability. Superficial considerations may suggest that Essay type examinations measure high order abilities, organisation, clarity of thought, with, ingenuity, originality and actually it has yet to be shown to measure anything of any significance whatsoever.

Regarding measurement of attitude, by essay type tests, the examinee may profess an attitude which is not genuine or which reveals his attitude on basic issues only.

It is also said that essay type test helps to secure a sample of the creative power of the examinees; but the fixed time and formal examination period is not ideal time or place to test the creative abilities. They are unreliable abilities and probably should not be asked in such examinations.

The essay type test also helps us to infer something from his answer about his insight and personality. But such inferences are difficult to draw and their reliability is always doubtful.

Students prefer to answer numerical problems and direct questions. Why ? Many workers in field have concluded that there is no solution to unreliability of grading subjective questions. Other means of testing should be developed. The consistency of reading objective test is perfect and it can be justified as measuring instruments, because it gives the examinee an opportunity to exercise important abilities which can be assessed from the product.

In essay test, the examiner allows the selection of a topic which he knows the most and optional questions are used. How can we compare different type of students ?

List of books for study

1. Hughes, J. M. (1957). Human Relations in Educational Organizations : Harper and Brothers Publishing Co. N. York.
2. Milwankee (1957). Karach, R. R., and Esterbroke, F. C. 250 Teaching Techniques Bruce Publishing Co.
3. Lindquist, E. F. (1959). Educational Measurement : American Council Education, New York.
4. Russell, J. D. and Judd, C. H. (1940). The American Educational System : Houghton Mifflin Company, New York.

Teacher-Student Contact

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Many detailed studies have been made regarding the complex relationship of teachers with the students in various parts of the world. Most of these studies point out that it is very difficult to have ideal teachers and ideal students, and that the problem of relationship between the two is far more complex and involved than is apparently estimated. However, relatively little information is available regarding the teacher-taught relationship in the agricultural institutions or other professional institutions of India.

Few would deny that good and effective teaching is the focal point of our professional educational system. In spite of universal recognition of the importance of the teacher, relatively little progress has been made in defining 'good teaching' or in specifying the distinguishing characteristics of competent teachers. In our institutions there is a very heterogenous group of teachers consisting of Indian, American, and other foreign trained individuals, and of people possessing diverse academic, social, emotional and cultural background. So also is the congregation of students in a class with very dissimilar and diverse attitudes and motivations. The relationship problem, therefore, assumes a significane of high magnitude. Coupled with this, there is also a great dissimilarity between the demands of teacher-taught relationship in this traditional educational system through which most of us have passed, and between the trimester or semester system which is now gradually being introduced in many of our institutions. All this makes a very intricate complex which becomes difficult to resolve in simple terms. However, in spite of all heterogenity and diversity of teachers and

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students, some significant achievements are on record wherein teachers have played their role in production of good students who compare with the best of any other country.

In spite of this, several complexities of the problem remain unsolved and as such the widespread riots and indisciplined action by students at various places in the country in the recent past are a clear reflection of the urgent need for taking further steps in this direction. Some of the common place difficulties have been well-enunciated by the Education Commission which are gradually being implemented. However, the responsibility of effective teaching and producing meaningful students still rests with the teachers.

Teaching is effective to the extent that the teacher acts in ways that are favourable to the development of basic skills, understandings, work habits, desirable attitudes, value judgements and adequate personal adjustment of students. For achieving this, good teachers are required, the lack of which is indeed a universal problem. Educators and laymen alike disagree widely on aspects of learning that should be emphasized and the role the teacher should play in a learning situation. It seems reasonable to expect that the teacher's roles vary in relation to the characteristics of the taught, to the grade level, and to the specified field of learning. Competent teaching, therefore, becomes a relative matter. The teachers' role thus becomes a basis on which the entire superstructure of educating the young rests. The teacher is basically involved in two ways with the students; in the class-room and individual student contact.

The Class-room contact : In an heterogenous group of students in a class, one of the most perplexing problem that confronts the teacher is learning and understanding the motivation of the students. While the central place of purpose in class-room learning is undisputed, difference of opinion arises over what purposes are to prevail. Shall the teaching be society-oriented? Shall the interest and purpose of students dictate the teaching programmes or should teachers and other learned people decide what is best for the student? The purpose and desires of both students and teachers may not always be matching except that the teacher is to complete the requisite course and the students are to pass that. Besides, a teacher may involve himself with developing the

intellectual or skill aspect of personality of his students, while another teacher may be more concerned with emotional and social development, and still another with the fostering of creative talents. The incongruity between the purposes of teacher and the varied motivation of class-room students thus erects a barrier in the proper learning process.

The pattern of activity of teachers in class-rooms is highly individual. Teacher and students have the most common purposes when they go on picnics, excursions, etc., but they have the greatest disagreement in their purposes for lectures, written examinations and library assignments. Discussions and lectures are the most frequent practices of the class-room activities. Examinations occur in the next greatest frequency and the least frequent are the excursions, picnics and motion pictures. Students consider excursions, picnics and friendly discussions to be of most value and other activities of least value. This is contrary to the actual happenings and requirements and on it hangs the balance of teacher's effective role in translating his purposes in relation to the student motivations.

The human-relation problem in the contact of teachers to varied types of students in the class is a notable feature. It has been experienced and established that the students who stand at the bottom of the class in their achievements, are in a much less effective relationship with their teachers and *vice versa*; whereas it is desirable that there should be a greater contact of low grade students with their teachers so that their gap of knowledge is engulfed. But this seldom happens. The dynamic inter-play between the teacher and student, therefore, suffers due to human element. The reasons for this are not far to see.

Another vexing problem that confronts the teacher in the class-room is the technique of control by which he attempts to have influence over the students. Undoubtedly the necessity of proper control and discipline in the class is a most desired feature in order to persue other activities, yet the methods adopted by different teachers vary from individual to individual. But the teacher is not left entirely free to control students. Society, comes in his way. The teacher demands that the student should sit still, study, understand, and memorize, while every muscle and feeling tone of the student urges to be off and away from class-room activity and to

explore the new world which daily opens to him. These and other factors result in a constant tension in the relationship between the teachers and the students.

The competence of the teacher in delivering his subject-matter to his class, his method of communication, his procedure of evaluating the students, is a highly individual matter. The objective of all these manifestations is that proper teaching codes are practised and that the students received maximum benefits in the class-room. These are procedural matters and are widely accepted principle, though these may or may not be actually practised by all.

The individual characteristics of the teacher in terms of his professional background, career, social and economic status, his interaction and position in the institution, and relationship and responsibilities towards his administrators greatly influence his make up of mind and reactions in the class-room. This in turn, determines whether the teacher plays a positive role in the class-room or not.

In fact the norms for teachers relationship with the class are well-established, yet their practice is far from satisfactory because of the human factor coupled with the lack of proper understanding of the teachers' attributes by the administrators and the educators who are the custodians of our educational machinery.

The Personal Contact : The present day students are more demanding, purposeful and highly motivated, though individual variations may be quite large. The personal contact of a teacher with the students requires him to be very verstile, understanding, and satisfying, as well as keeping in mind the influence of his personal traits on the students. The interaction, therefore, is far more complex than is envisaged for class-room contact.

The student advisory system in the form of tutorials, wherein a few students are attached to a teacher, is designed to foster better understanding and close personal contact of the teacher with the students. The objectives of such contacts, though very necessary and useful, are difficult to achieve due to several reasons. The personality of a teacher, his social, economic, political and academic characteristics

will be guidelines in his reactions to the demands of the students. The understanding of the various values of life by the teachers has a direct impact on the student contact, whereas individuals in an institute may vary greatly in their outlook towards extra class-room activity. The purpose of personal contacts are indeed well-defined, but the translation of these into practice is the real crux of the problem.

The students look upon this opportunity of personal contact with the teachers with different motivation. For some, the teacher is a guide for his professional activity, for others he is like an elder friend, while quite a few students are indifferent towards this relationship. Within a small group of students who are attached to a teacher all the variables may exist in different degrees. This reflects the wide range of requirements of the students.

The operational norms and the *modus operandi* of the teachers' role in student contact are not well-defined because of several practical difficulties, even though the objectives are very clear to both the students as well as the teachers.

In conclusion it may be stated that although everyone is convinced of the desirability of teacher's role in building up the youth, yet the operational features are not properly understood and practised. The reasons for this can be easily traced to the variability in purposes and motivations of the teachers and the students in the class-room or outside. Individual factors, cultural, academic and other characteristics greatly influence the operational part. The osmosis of ideas from teacher to students depends upon the willingness of the latter to receive, them and to digest the same. The complexity of the problems involved in this interaction is one that needs urgent attention of all who are vested with the responsibility of preparing our youth as desirable citizens of free India.

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Philosophy of Higher Education in India

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Philosophy of Higher Education in India :

(i) *Aims and objectives :* The aims and objectives of education might differ somewhat as to whether a narrow or broad view is taken and also whether the special age group or requirements necessitated by local, regional, national or international conditions are taken into consideration. The four-fold general objectives that will hold good under all conditions, according to Henderson (4) are :

(a)	Self-realisation ..	Development to maximum extent of the intellectual and other faculties.
(b)	Learning of relations of all types	(Well-adjusted personality).
(c)	Economic efficiency ..	A person better suited for material life.
(d)	Civil sense ..	A person with well-developed sense of rights and obligations.

(ii) *Curriculum or content :* The quality of product coming out of any institution apart from other collectoral factors, is considerably dependent on the quality and quantity of the subject-matter taught to the students. It is axiomatic that more challenging subject-matter in the form of curriculum covered throughly is sure to yield students of better quality than either a reduced content covered throughly or over exhaustive content but not taught in its entirity. A good curriculum at the college level should include general edu-

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cation, vocational preparation, special interests and work experiences. Keeping in view the present needs, level of development of the society and facilities available in India the following guidelines are suggested :

(a) Teaching of languages and arithmetic along with certain amount of general science up to primary standard.

(b) Continuing the teaching of languages and mathematics and adding such subjects as social studies, science, drawing etc. up to the middle school.

(c) Two types of syllabi at the high and higher secondary stage :

(i) Terminal education with provision to learn a vocation of interest to the students.

(ii) Continuing education with emphasis on basic sciences and humanities.

(d) Professional and basic sciences to be taught in the colleges. The luxury of the study of pure arts and humanities should be stopped forthwith. The colleges of Pure Arts which are places of refuge for the third divisioners must stop wastage of the time of these students who should either strive hard at the high school to obtain good marks to be eligible for science colleges or know straightway that there is no further entrance for them for higher education.

If the above scheme is implemented, there will be many more productive hands leaving high and higher secondary schools. These schools in the final years, should teach such vocations as Typing, Wireless Operation, Accounting Officer routine, etc., so that the students can take up jobs immediately without waiting for any further training. There should also be technical institutes that can train technicians.

(iii) *Procedure and methods of teaching* : There is a need to replace the conventional method of imparting instructions through simple lecturing and then expecting the students to memorise facts to be reproduced at the time of examination. There does not appear to be a ready substitute for rote-memorisation at the school stage where the steps of Thorndike, namely readiness, exercise and result, in the learning-process hold good. The child must be in a state of readiness (mentally

set) to learn, then exercise (exert) and the result of the two shall be learning. However, in institutions of higher learning, the formal-lecture method of teaching ought to be used only sparingly. In its place, discussions home assignments, library readings, practicals in the laboratories and other group and idividual methods requiring greater effort on the part of the student, should be substituted.

(iv) *Environment, including facilities :* Opinions will continue to differ as to what should be the minimum, normal or best environment and facilities under which instructions may be imparted. Whereas, the idealist will first insist on the ideal facilities to initiate instructions, the Realist and for that purpose pragmatist would like to get started with whatever is available and endeavour to obtain the most desirable situation. There is nothing to dispute that ideal environment and facilities are highly conducive to efficient teaching and learning; yet the facilities alone cannot take care of any other deficiencies regarding the content the quality of the students or teacher. The best approach will be to take advantage of the readily available physical facilities and patiently try to improve upon these.

(v) *Educand :* Who should be the educand appears to be an innocently simple question but in case a satisfactory answer of this could be found and implemented, many of the weaknesses and evils of any system of education will vanish. The universally accepted truism is that there should be free opportunity of education for every citizen of country up to the primary or middle school if not Higher Secondary level. This simple proposition is hard to put into actual practice in a country like India. Here, higher education is not sought solely by those who possess the necessary intellect and capability; but in many cases by those who realize that there is higher value attached to a college graduate. If somehow, it could be assured, as has happened in industrially-developed countries like U.S.A. and others that the earnings of a person going to a college are not going to be markedly different from another person who enters a profession after high school graduation, then there may not be such an undue insistance on going to a college. Unless this is brought about in actual practice, all advice or suggestion to improve the quality of Higher Education shall remain a platitude. Most of the

efforts to bring about qualitative improvement in higher education are frustrated by an unusually large number of unwanted students in the colleges.

A desirable proposition shall be to universalise education up to the High School and it shall be seen that every child is educated up to this standard. Thereafter, institutions of learning with professional bias should admit only those few who possess the necessary intellect and potentiality. There should be a chain of polytechnical institutes for preparing technicians needed in various industrial and other establishments.

(vi) *Teacher* : There is a need to correct the current anamoly in the teaching profession in that only the leftovers from other professions are attracted to this field even though it is charged with a responsibility of the highest order, i.e., building the character of the youth. It is said that teaching in schools and even in colleges is the last refuge of an educated person who is unable to find a more remunerative job. Although India is not the only country where the emoluments of the teacher lag far behind their comparable counterparts, yet the differences in this country are much more pronounced than elsewhere. The subterfuge that teachers, after all, must not care only for their financial emoluments, has already done considerable damage to the cause of education in as much as teachers of poor intellectual attainment are taking up this profession. A teacher with poor academic record in school or college can hardly inspire his students for high academic achievements in at least two distinct ways. He can hardly satisfy the talented students of the class and secondly he sub-consciously and sometimes even consciously discourage scholarly achievements by such disparaging remarks to the gifted student as 'bookish' or 'theoretical'. There is, thus, no substitute for appointing teachers of high scholastic performance and this is obviously possible only if sufficient remuneration is offered to them.

In a nutshell, the philosophy of higher education for India under the present prevailing conditions can be stated in these words. The aim of Higher Education should be the highest scholastic achievements for which highly challenging and rigorous curriculum should be drawn for every discipline so that only talented students may plan to go in for higher

study. The instructions should be imparted in such a manner that the inherent faculties of the students are developed to the highest extent. An environment, including facilities which is conducive for best learning should be provided. No price may be considered as exhorbitant for this purpose. The students or teachers must not be handicapped or starved for want of the needed facilities. Only those students who have the necessary intellect should be permitted to enter an institution of higher learning and teachers of the highest scholastic calibre and attainment should be attracted to teach in such institutions.

Significant improvement cannot be expected in the quality of education if the emphasis continues to be laid on the quantitative and numerical achievements. Education at the higher level, particularly should not be viewed as a mechanical and routine process involving the mere physical presence of the concerned ingredients. A proper understanding and careful attention to the following concepts concerning the process of education can be expected to lead to improvement.

The student	..	A living being for carrying on responsibilities of life.
Behaviour	..	Activity or effort that the student makes overtly and covertly; all thoughts, feelings and physical movement *(inside and out) called into play by* the affecting stimuli; all that an individual does to control the situation in order to care for the values considered desirable.
Environment	..	Everything apart from the student that affects his behaviour either directly or indirectly.
The situation	..	The environment at a given time that the student sees according to his experience.
Goal seeking	..	The act and fact of setting aims and pursuing them, all actions of human beings are with a purpose and man is a goal seeking living being.
Preferences	..	Discriminatory responses to the stimuli which determine the pace and quality of goal achievement.

Feeling .. That aspect of behaviour which concerns pleasure or pain, satisfaction or dissatisfaction; feeling set pace for action.

Thinking .. It connotes all that the student does in advance for an overt action to size up the situation and make plans for dealing with it; during action, to evaluate the process and shift the means, if need be; and after action to draw reasons for the future.

There are a few of the several aspects that need to be understood properly for bringing about improvement in the standard of educatton.

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Audio-Visual Aids in Teaching Methods of Science Subjects

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The need : Communication is at the root of all activities. It is through communication that human beings share knowledge, information and experience, and thus understand, persuade, convert or control their fellows. Means of communication are many and varied. They comprise all possible ways of attracting attention. We communicate by facial expression and gesture, by touch, by pictures and visual signs, by mathematical and scientific signs and symbols, by music and dance, and, most important of all, by words, spoken or written.

The citadel of effective and efficient teaching-learning process in and out of class-rooms, is communication. The entire process of education owes its success or failure in a system to the nature and quality of communication. A widespread chaos and confusion, stresses and strains and pulls and pushes, operating so strongly in the educational system of today, has made one gasping as to what would happen to the future generation, if the pathogens are permitted to have their free inter-play and eat into the very vitals of head and heart of both the teachers and the students.

Education aims at the proper growth and development of individual's personality in all its manifestations. Apart from all other inputs, imparting of adequate subject-matter knowledge to the students is, probably, the most important one to achieve the desired objective. Its importance is much more magnified in the teaching of science-subjects. It is all

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the more important in Agricultural institutions where all the knowledge and principles of science have to be tailored according to the needs and requirements of those who have chosen to enter into the profession of agriculture after completion of their educational pursuits.

The realization of the importance of communication in effective teaching-learning process leads one to be very specific in respect of the application of such techniques of teaching methods that will result in desirable communication and thereby proper teaching-learning. In other words, the 'how' of teaching is most important for effective communication of 'what' of teaching.

Of late, disturbances of varying magnitude in different colleges and Universities of India and elsewhere, have led many an educationist ponder over whether the educational system needs some improvement because of some inherent drawback implicit therein. May be, there is really something lacking in every educational system operating in this world. Nevertheless, how about giving a serious thought to the ways and means that could and must be employed to make the existing educational system really apt and appropriate ? Further, can it be claimed that everything is good under the shield of teaching method and there is hardly any room to improve it for attaining the aims of education, specially in technical institution ? I am one of those who believe that there is enough scope of improvement mainly in the teaching of science subject in every institution including Agriculture. This assumption stems from the following considerations :

1. Highly sophisticated technical know-how of the teachers is no guarantee that their teaching will carry the gun through to the desired extent.
2. There is hardly any provision of adequate orientation of the teachers who enter into Agricultural Institutions, in the art and techniques of teaching methods.
3. Growing disatisfaction amongst the teachers and students regarding the obtainment of adequate knowledge of the subject-matter by the students.
4. Regular complaint by the students and even the authorities that in the same institution, some teachers communicate so nicely that the students

understand quite well and are able to retain much longer.

5. While individual differences amongst teachers is a natural phenomenon, there is an urgent need to streamline such guidelines of teaching methods which must be made known to the teachers of *Agricultural Institutions so that they can deliver* the real goods.

Audio-Visual Aids—A Teaching Tool : Adequate knowledge and application of teaching methods of science subjects due, thus, a necessary pre-requisite for effective teaching-learning process. While the scope of discussion on teaching methods is too wide, it is considerred deisrable at this place, to delimit only to the use of Audio-Visual Aids in teaching methods of science subject.

Audio-Visual Aids have been used in education from the earliest time. It is, however, only in recent years that their use has been recognized on all hands owing to the enormous expansion of education and increase in the number of pupils. The use of modern Audio-Visual Aids *in teaching methods is* a relatively new movement in our country although it has a very valuable contribution to make in developing good educational techniques. In the words of SAIYIDAIN (1957), "In recent years, its concept as well as its cope have been widened *considerably and new instruments have* been pressed into its service. Many of our teachers, however, are not fully aware either of what is being done or what can be done, through these aids, to make the process of learning more intelligent, interesting, and firm."

The importance of Audio-Visual Aids in teaching of science subjects is all the more important because of the devetailed relationship between theory and practice as a trait of science. In nutshell, the following benefits accrue from the judicious application of Audio-Visual Aids in teaching science :

1. It *motivates student's learning by arousing his* interest in a number of ways as :

   (a) They provide a change from the usual activities of reading, writing and listening.

(b) Aids provide a change in the atmosphere of the class-room.

(c) They are relatively easy to understand as they interest the students more than the mere description of anything through talks only.

(d) These aids also provide opportunities to the students to do something. An opportunity to touch a model, press a button, or turn a crank, gives an added appeal.

2. Audio-Visual Aids make the learners' experience meaningful. This is so because "audio-visual materials supply a concrete basis for conceptual thinking; they give rise to meaningful concepts to words enriched by meaningful associations. Hence, they offer the best antidote available for the disease of verbalism." For example, the description of an insect, or an animal about its height, colour, head, leg, etc., will hardly help the students in forming a correct idea of the insect or animal in question. But what would happen if they really see it for themselves ? Experience thus gained will be purposeful and its knowledge can be retained much longer.

The opportunities of direct experience may be limited. Hence, there is need to fall back upon some other aids. Further, if the object is too-big or too small, direct experience may not be much helpful. As for illustration, a visit to an industrial complex may not provide adequate learning to the students while a model might be much more helpful and beneficial. Similarly, learning about bacteria, spores, physiological systems of plant and animals, etc., will be much more effective and lasting if models, slides, etc., are made use of by the teachers.

In short, aids can be effectively used in teaching because they :

(a) Invite cooperation.
(b) Attract attention.
(c) Supplement verbal information.
(d) Hold attention.
(e) Illustrate relationships.

(f) Provide challenge.
(g) Consolidate teaching-learning.

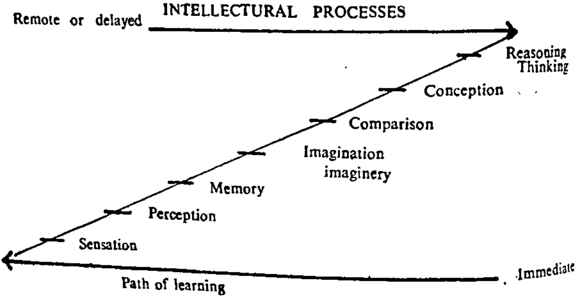
Dale *et al.* (1949) have also highlighted the following advantages of Audio-Visual material on the basis of research work :

(a) They supply a concrete basis for conceptual thinking and hence reduce meaningless word responses of students.
(b) They have a high degree of interest for students.
(c) They supply the necessary basis for developmental learning and hence make learning more permanent.
(d) They offer a relativity of experience which stimulates self-activity on the part of pupils.
(e) They develop a continuity of thought; this is specially true of motion pictures.
(f) They contribute to growth of meaning and hence to vocabulary development.
(g) They provide experiences not easily secured by other materials and contribute to the efficiency, depth, and variety of learning.

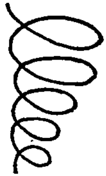
Again, Rulon at Harvard and Arnspiger at Columbia in separate researches found up to 22 per cent gains by groups using films in science, social studies, and music, over groups taught without film (Kinder, 1954). They further reported more retention on the part of the students because of the use of aid.

It has also been found that, in the main, utilization techniques do not vary a great deal, regardless of the instructional materials used. In all cases, the pattern emphasizes the presence of a dynamic teacher, variety, active student participation, checking up on things learned, follow-up, and application (Dale, *et al.*, 1949).

Hence, the student should be provided with a wide range of direct and contrived experiences which will provide a basis for meaningful learning. In other words, the student should have sufficient precepts to enable him to develop significant concepts. The paths of learning can be better depicted in a somewhat summary fashion as follows :



The development of a concept can be further explained by an inverted spiral system that starts with rudimentary perception and broadens with experience as :



The foregoing discussion, however, does not imply that the aids are not in use by the teachers specially in Agricultural institutions. But the main idea of this article is to discuss thread bare the desirability of adequate knowledge of Audio-Visual Aids by all the teachers so that they are better equipped to make their teaching more effective and efficient.

Key points for the use of Audio-Visual Aids : The effectiveness of Audio-Visual Aids is directly dependent on

their proper use. The entire use of Audio-Visual Aids can be classified as follows :

A. Planning
B. Preparation
C. Treatment (Application)
D. Follow-up

A. Planning

Selection : There should be a proper selection of audio-visual aid which depends on the following factors :

(i) *Topic under study :* The aid selected should be such as to cater the specific need of the students and the teachers. For example, in a lecture on the 'Life cycle of Mosquito," it is not desirable to show a film entitled, "The Mosquito", which may have everything except the life cycle. Hence, the need of a careful selection of the aid keeping in view the specific objective.

(ii) *Aid should have the tinge of local environment :* A teacher of Agronomy gives a very good lecture on the cultivation of hybrid corn and then supplements his teaching by arranging film show on 'Hybrid Corn' produced in the U.S.A. While there is nothing wrong in showing such films, but the lesson may not be as effective because of the students' unfamiliarity with the environment in which the cultivation of Hybrid Corn was shown to them.

(iii) *Aids compatibility with the age and intelligence of the students :* The aid should be so selected as to suit the average level of the students of a class. A film-strip on 'tracer element of soils', 'hybridization', etc., may be very desirable for the students of final year of B.Sc. (Agri.) and post-graduate classes, but may be of less importance to the first year students of B.Sc. (Agri.).

(iv) *Good physical condition of the aids :* Old and damaged aids should not be used for teaching purposes under any circumstances.

(v) *Avoidance of too many selection of aids :* A teacher must visualize the number of aids that must be

included while making meaningful learning to the students as selection of many audio-visual aids by a teacher, provides more confusion to the students' learning rather than encouraging specific learning.

(vi) *Preference of simple aids :* Every care should be taken to ensure that simple aids are selected for effective learning. However, this must not be practised at the cost of meaningful learning.

B. Preparation :

This refers to the mental preparation of both the teachers and the students in order to have effective teaching-learning process.

By teachers : It is absolutely essential for the teacher to know the 'why', 'what' and 'how' of the aid. He should be in a position to fit the aid quite well in the teaching programme.

On the part of students : The student should also be psychologically motivated and his interest aroused before the aid is finally used as a teaching tool. In the event of any finer and subtle points, the teacher should explain it to the students before hand in order to ensure effective learning.

C. Application :

Proper application of the aid is equally important. The aid should be used in such a way that it is quite audible and visible to the whole class with equal efficiency. This condition, however, can be fulfilled in the presence of the following pre-requisites :

(i) Good condition of the aid.
(ii) Thorough knowledge and skill of the teacher about the proper and efficient handling of the aid.
(iii) Proper physical condition.
(iv) Darkening arrangements, if need be.

D. Follow-up :

This depends to a great extent on the objective of the teacher with regard to the presentation of the aid. Important

points should be discussed with the students after they have seen for themselves the idea contained and conveyed through the aid.

Some important Audio-Visual Aids : After having dealt the general guideline for the use of Audio-Visual Aids in Teaching Methods of Science subjects, it is considered worthwhile duscussing some of the most important aids, the knowledge and skill of which are desirable on the part of all those engaged in teaching science in Agricultural Colleges or Universities of the country.

(i) *The Chalkboard :* It is one of the most important aids available with the teachers and it helps in getting standard, neatness, accuracy and speed. It is a great tool in the hands of the teacher to emphasize important points of his teaching. The chalkboards are of two types—(a) Black and (b) Yellow or Olive Green. The latter type is in vogue in U.S.A. and Great Britain.

Again, teaching of science subjects needs a roller type of chalkboard with a matt surface :

Points for using a chalkboard :

(a) Clean it with eraser.
(b) Should be written in straight rows starting at the top left corner.
(c) Only a few most important points to be written.
(d) Should be written bold so that it is quite visible from the back if the class.
(e) Uncommon abbreviations should be avoided.
(f) Planning in advance for the matter that is to be written on the chalkboard.

(ii) *Charts :* According to Dale (1954), a chart is "a visual symbol summarising or comparing or contrasting or performing other helpful services in explaining subject matter".

Charts are of various types viz. :

Table chart	..	Presents information in ordinary sequence.

Tree chart	..	Highlights development or growth of a thing.
Flow chart	..	It is known by lines, arrows, rectangles, etc. to depict the organization or structure of an organization, institution, etc.
Iso type chart	..	This is a pictorial representation of statistics.
Pie chart	..	A pie or a circle is divided into segments, each representating a percentage of the whole.

The use of a chart can be more effective if it is combined with other aids. For example, a chart used with a model can communicate information more vividly and clearly. Likewise, charts can be combined with films, filmstrips, etc.

The following points should be considered while using chart as an aid in a teaching method :

(a) Large, short and neat heading.
(b) Complete and simple idea.
(c) Related to topic or a comparison of two ideas.
(d) Support of other related aids.
(e) Large enough to suit the size of the class.

(iii) *Diagram :* It is a drawing with the help of lines and geometrical forms for the sake of explaining some idea, event, object, etc. It is a very important aid in teaching science subject as it shows casual relations and structure of objects and apparatus.

The diagram, should be preferably used with the original. In other words, it would be much more helpful for the students' learning if they are shown the actual flowers while showing its diagram. In the absence of original material, diagram should be combined with pictures, films, filmstrips, etc., for providing better learning experience.

It should, however, be always ensured that the diagrams are prepared before the students and that too in stages i.e. all aspects should not be shown all at once.

(iv) *Models and Mock-ups :* These are of great importance by way of providing a good substitute of direct

experience. It may not be always feasible to have a real thing in the class-room due to its being too complex, too big or too small. Models are invariably used as substitutes in such situations for imparting instructions to the students.

A model is a three-diamensional recognizable imitation of an object and conveys the meaning quite effectively. Description of an animal, its physical features, discussion on topics like—Heart, arterial, or nervous or respiratory or digestive system, idea about some complex structure viz., Bhakhra Dam, etc., can be very effectively communicated with the help of models.

Types of Models :

Scale Models : Correct representation of the object demands exactness in the model. For example, a correct idea about the Bhakhra Nangal and other projects can be very well presented through some small scale models.

Working Models : It represents the operation or function of the object in a simple way, viz., working of human heart.

Simplified Models : These provide learning experience to the students although exact dimensions may not be used. The animals, birds, fishes, etc., made out of clay, sand or straw have great educational value for the science students.

(v) *Specimens :* A specimen is a real object except that it lacks the natural setting. A Mexican wheat plant with profused tillering and grains can very easily communicate as to how does a Mexican wheat plant look like, although it may not be a standing plant in a wheat plot. In the like manner, the specimens of insect, fishes, birds, crop plant, implements, etc., are used in teaching methods.

If need be, photographs, films, etc., can be used to provide the natural setting as a support to the specimen in question.

(vi) *Slides and Filmstrips :* A slide is a transparent picture projected by shining light through it. The most widely used sizes of slides are 2″ x 2″ and 3¼″ x 4″. They

may be made of a variety of materials—clear glass, etched glass, coated glass, sensitized glass, cellophane, etc.

The filmstrip is referred to as filmstrip, filmslide, stripfilm, and slide film, etc. It is, however, a role of 35 mm. positive film under any name. It has sprocket holes in both margins and contains a sequence of pictures and has a series of still pictures usually called frames.

The single frame filmstrip is more widely used and gives a $\frac{3}{4}'' \times 1''$ picture. The double-frame film pictures are $1\frac{1}{2}'' \times 1''$ and are printed so that the width of the picture is along the length of the film, which is run through the projector horizontally.

Slides and filmstrips are particularly useful when detailed analysis is required. Filmstrips offer a wide coverage of subject-matter while the slide can project only one idea or object at a time.

The sufficient use of slide and filmstrip demands the consideration of the following points :

1. The teacher must prepare in advance.
2. The class must be prepared.
3. The equipment should be made ready in advance of presentation.
4. The students should participate during the presentation.
5. Proper follow-up must be done.

(vii) *Tape Recorder* : Judicious use of the Tape Recorder goes a long way in introducing to the science students scientists—living and past in the most thrilling and original fashion. Its use lies, besides this, in recording and playing back, sounds from those objects which are shy of human presence, such as various fishes etc. The tape recorder can be operated and left isolated to record such sounds.

(viii) *Movie and Still Pictures* : Camera tacts and techniques may provide uncommon experiences to the learner. Light shy objects or heat intolerent objects which cannot be seen with the naked eye, such as various types of amaeba can be photographed in the darkness under infra-red light, or on infra-red film. A naked eye cannot see what happens

to a drop of rain falling on the ground. Camera recording the scene, say at about half a millionth of a second may help a scientist studying rain and its moisture absorption capability of a particular rock or soil in relation to the spreading capability of rain, by showing the actual position.

Photomicrography through radio microscopes analyses the minutest structures of a material. Photography with the aid of a radio telescope may help teaching a student of science what actually happens on the surface of the sun, and how it affects weather.

Movies have a still larger role to play. A movie camera with its time lapse technique may show the growth development of a plant in a living manner which the eye cannot perceive.

These rare experiences brought to the class-room add reality to the teaching of science and make it more effective. Moreover, the ultimate aim, of any teaching method in science is to lead the students to discover facts himself and acquire a first hand knowledge of the same and acquire an aptitude for the study of science and to guide him to further research.

To summarise, films show motion as follows :

(a) Movement which is observable.
(b) Movement too slow to be perceptible.
(c) Movement too fast to be observable.
(d) Motion depicting objects and events separated by intervals of time and space.

(ix) *Television :* The speed with which television is spreading throughout the world is one of the technological phenomena of our time. Still, it is only in recent years that educational institutions of U.S.A. have started making wide use of television in class-room teaching, training of teachers, extension services, etc. Uncertainty about the stay of highly qualified teachers in agricultural colleges, increasing number of students, the need to keep pace with the day-to-day technological development, and complex nature of agriculture, etc., demand finding such ways and means that will produce desirable result through teaching in Agricultural Colleges.

Television is only one of these ways among the material aids to instruction, which can contribute to the scientific improvement of conditions in schools and colleges. Television in America, occupies a prominent position in order to make valuable contributions in the improvement of teaching-learning process.

Television may be broadly divided into two groups.

(a) Broadcast Television (B.T.V.).
(b) Closed Circuit Television (C.C.T.V.).

Broadcast television is very much useful in science education. Experiments conducted in sophisticated laboratory by an eminent teacher can be demonstrated to a large group of students scattered at far away places.

Closed circuit television has a special advantage that the system can be employed and self operated by a single institution. Experiments conducted in a laboratory or the operations performed in an operation theatre can be demonstrated to a large number of students made to sit around a number of television sets.

When television lessons are presented with imagination, where students are stimulated to active participation, in short when television teaching is at its best, it makes a distinct contribution to the institutions (Crassirer, 1960).

Again, television teaching depends on the perfect functioning of electronic devices. When mechanical failures take place, when pictures or sound is received inadequately, the class-room teacher can do no more than improvise a substitute lesson, and the class is bound to lose the thread of the day-by-day sequence of television lessons.

According to Tyler (1958), the use of television to educational institutions can be classified as follows (Tyler, 1958) :

(a) Total television teaching.
(b) Supplemented television teaching.
(c) Television supplementing class room.
(d) Television as a teaching aid.

There is no hard and fast rule for the above classification. In fact, it may be difficult to distinguish when the teacher supplements television and when television supplements the teachers lesson.

Television reveals both weaknesses and strength in education. It also needs team with between the television teacher and the class-room teacher.

Conclusion : One of the ways to make learning concrete and meaningful is through audio-visual or instructional aids. Learning has been conceptualized as change in performance through conditions of activity, practice and experience (Bernald, 1965). It is a response on the part of the students. But good teaching demands a positive and desired response. If an educational system has failed to bring about a desirable change in the behaviour complex of the students, the world of tomorrow will be all dark and dreary. The problem is further accentuated due to the existance of varying capacity and capability of the student of a class. It is all the more complex in an Agricultural College, the students of which, have already developed some complex in their personality in comparison to their counter-part of Medical, Engineering and even Veterinary colleges.

The aforesaid complexity, therefore, calls for an ever agile teaching community so that the main purpose of education is never lost sight of at any stage. And the turn out of these colleges must have adequate knowledge of the subject matter and be full of all interest, zeal and enthusiasm when they enter into their profession. It is at this stage that the importance of Audio-Visual Aids in effective teaching method comes to the fore. One teacher is constantly called upon to ensure that his teaching must result in meaningful learning experience of the students. Good teaching is an elusive concept. It is difficult to define as it refers not only to something static but to something dynamic and evolving.

It is believed that a teaching reinforced with Audio-Visual Aids, makes learning more effective and meaningful. Any material or technique that makes learning more dynamic and more realistic will definitely foster better learning.

In the preceeding pages, some of the most important

audio-visual aids needed in teaching of science subjects in Agricultural Colleges, have been elaboratly discussed. The list is not all pervasive. Moreover, it would be quite erroneous to conclude that judicious application of audio-visual aids in teaching is the panacea of all ills of insufficient and undesirable learning on the part of the students.

It must be recalled that these audio-visual aids are first a tool in the hands of a teacher and it is up to him to decide upon which to use and how to use in a given class-room situation.

Of late, there has been a phenomenal increase in the use of Audio-Visual Aids in different institutions and organizations for meeting their specific needs and requirements. In fact, every teacher inclusive of Agricultural College, can considerably improve his teaching and thereby learning, if the following conditions are satisfactorily met with :

(i) To overcome the limitations of restricted personal experiences of the students.
(ii) To overcome the limitations of the class-room.
(iii) To provide for the direct interaction of students with the realities of the social and physical environment.
(iv) To provide uniformity of precepts.
(v) To give concepts which are correct, real and complete.
(vi) To awaken new desires and interests.
(vii) To provide motivation and stimulation, and
(viii) To provide integrated experience which vary from concrete to abstract.

Audio-Visual Aids have a great future in all walks of communication processes. Its importance has grown manifold due to the complexity of educational pattern and ever changing needs and requirements of the community. Those who can make the best use of these aids are bound to turn out good students with integrated experience and desired behaviour to suit the sanctions of the society.

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Necessity of Congenial Environment for Preparing the Young Scientists

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There are three main types of environments which directly influence the young scientists :

1. Economic environment.
2. Social environment.
3. Scientific environment.

Economic environment which provides security is by large the reflection of national economy of any country. However, the education policy of any country and the value attached to the scientific development, are also the major factors which influence the economic environment of our institutions, which in turn directly affects the preparation of young scientists. Scientists in the majority of institutions have very little say in allocating the budget for scientific development at the state or national level, therefore, we cannot expect these scientists to alter the economic limitations, in the training of young persons. Without elaborating too much on this point, I would like to mention that financial assistance to young persons during their period of training and a secure financial future after completion of their training are major factors which will help to get good students in the field of science. With proper guidence and training, these students can be turned into brilliant young scientists. Substantial financial grants for graduate assistantships and post-doctorate fellowships in some of the developed countries like Canada and America are attracting the best scientists young and old from all over the world. Without

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economic incentives it will be very difficult to find good brains which can be trained into brilliant young scientists.

Before proceeding to the next two environments, it will be worthwhile to explain the meanings of a term which will be frequently used in the text.

"Donor scientist or concerned scientist" is referred to as the person who is involved in the training of a young scientist.

The last two environments, i.e. social and scientific are directly influenced by the donor scientists or the teachers. At the same time these two environments are very much inter-related. Let us say that the scientific environment created by donor scientist is related to the social environment in which he lives or has lived. Similarly, social environment is also greatly influenced by the scientific environment created by the members of its society. Therefore, we will have to admit that the scientific environment of our institutions, which are the training centres for the preparation of young scientists, is greatly influenced by the social environment of our society which produces the donor scientists and the young scienists as well.

Social environment or the congenial social atmosphere is created by an individual, a donor scientist. The teacher in this particular case, is the reflection of his temperament, his background in social sphere, his background in *academic sphere and many more factors. Therefore, the* creation of a congenial or non-congenial environment in the institutions by scientists or teachers is not a single step event, but is the product of a sequence of events. Now let us try to trace the origin of the environment which is present in our laboratories and institutions, of which the young scientists are the direct products.

The environment which exists in our laboratories and institutions is greatly influenced by the attitude of our scientists and administrators who are in turn affected by the social environment of our society. The young scientists undergoing training have to adapt themselves to the environment of the institution in general, and the environment of concerned scientists and teachers in particular. This adaptation of the young scientist to his concerned teacher can be for the better or for the worse. Therefore,

the need of creating a congenial environment in the institutions by scientists and administrators can hardly be over-emphasized.

The development of a particular kind of environment is a vicious circle. Once a particular kind of environment has impregnated any society, it will keep on expressing itself in families and institutions. If social environment of any society is healthy, we can, under normal conditions expect a similar healthy environment in the laboratories and institutions and the same healthy environment will be present for the development of young scientists.

Once such a cycle of congenial environment begins operating, it becomes a routine process and the development of young scientists in such an environment keeps proceeding in the right direction.

However, serious problems are encountered, where the environment of the society or the institution, for the development of young scientists is not ideal. For example, in our society. I personally feel that the mental development of our children, which can be our future young scientists, is far from satisfactory. It would not be an intellectual error to say that our children have very little freedom of thought and action. Our children are very much suppressed by stereo type thinking of their parents and elders. Once they start going to school there is hardly any opportunity for development of their individuallity. They are consistantly under pressure to conform to the thinking of their teachers. I imagine the same is true, when these youngsters start going to colleges and universities for undergraduate training. Therefore, under such circumstances, we end up with masses of students, who by this time are infused with a mental barrier for original thinking and its expression. These are the very young people who come to universities for post-graduate training in science. I believe that the primary function of research in any branch of science, is to reveal the truth about the unknown. We can hardly expect the young students without the power of original thinking and frank expression, to fulfil this function of research in science. In other words, we cannot expect our scientists and institutions, to prepare brilliant young scientists from the youngsters who have been denied a congenial environment throughout their past

development. In such cases, the institutions, scientists and teachers in particular, have two alternatives : either they accept these young scientists as they are and do nothing to alter the effects of the uncongenial environment of their past or they should change the outlook of these young scientists by creating a congenial environment in the institutions. I believe that the acceptance of the first alternative will be shirking the responsibility on the part of the teachers and scientists. The teachers, scientists and administrators of the universities should realize that they cannot expect any society or family to create a congenial environment spontaneously. It is the duty of the intelligentsia of the universities to counteract the effect of non-congenial environment on the young scientists of their past. By preparing young scientists in a congenial environment, we may be able to infuse a healthy and congenial environment into our society, which in turn will produce better brains for the preparation of young scientists. However, if the universities fail to create a congenial environment, we cannot expect any change in the environment of our society.

The third factor which affects the preparation of the young scientists, is the scientific environment which prevails in our institutions and laboratories.

I believe that the best way of illustrating this point will be by narrating the stories of two great scientists of 16th and 17th century. Copernicus (1473-1543) after studying in the university of Cracow went to Italy. By the time he was 27 he had become Professor of Mathematics in Rome. Before Copernicus, it was firmly believed that the earth is at rest in the centre of the universe while the sun, moon, planets and system of fixed starts revolve around it. According to the new theory of Copernicus, published in his great work "On the Revolution of the Heavenly Bodies" he tried to persuade the world that the earth is far from being at rest and it revolves around the sun. However, from fear of inquisition by the ecclesiastics, he put forward this theory as a hypothesis and did not assert it as a positive truth. However, when we see the reaction of some of the eminent pillars of society at that time towards Copernicus, it becomes shockingly clear that the environment of that time was far from being congenial for the development of scientific thought. Luther said, "People give ear

to an upstart astrologer, who strove to show that the earth revolves not the heavens or the fermament, the sun, and the moon. Whoever wishes to appear clever, must devise some new system which of all system is of course the very best. This fool wishes to reverse the entire science of Astronomy." We know now that Copernicus reversed the entire science of Astronomy to reveal the truth about the position and dynamics of these heavenly bodies. Actually Copernicus never confronted directly with the opponents of his theory. He used the tactics of appeasement which sufficed for a long time and it was only after Galileo's bold defiance that brought retrospective official condemnation upon Copernicus. Galileo (1564-1642) is one of the most notable figures in the history of mankind. His father was an impoverished mathematician and he wanted his son to go into something which he thought would prove more lucrative. At first his father was successful in preventing Galileo from knowing that there existed the science of mathematics. However, when Galileo was 19, he happened to overhear a lecture in Geometry, which was to give him all the charms of a forbidden fruit. I believe that all of us are familiar with the contribution of Galileo in the fields of mathematics and astronomy. However, one example, which clearly depicts his method of revealing the truth in science should be mentioned here. Aristotle before Galileo, believed that the speed with which a body falls is proportional to its weight. Galileo who was a professor at Pisa, but had no feelings for the other professors of his institute, used to drop different weights from the tower just as his Aristotalian colleagues were on the way to lectures. Big and small lumps of lead would reach the ground simultaneously which proved to Galileo that Aristotle was wrong. To other professors, Galileo was wicked. Galileo believed in finding truth in experiments whereas his colleagues considered books as the only source of eternal truths. Actually the suffering through which Galielo had to pass was caused with the invention of the telescope. Galileo confirmed that Copernicus was right when he claimed the rotation of the earth around the solar system. About Galileo's confirmation of the Copernican theory Father Inchofer, again an influential member of that society had this to say, "the opinion of earth's motion is of all the hear says the most abominable, the most pernicious, the most scandulous; the immovability of the earth is thrice sacred; argument against the immortality of the soul, the existence of God and reincar-

nation should be tolerated sooner than an argument to prove that the earth moves." I think the use of the above words need no explanation to judge the feelings of such people towards Galileo's confirmation of the Copernican theory. Eventually Galileo was tried by the Inquisition and forced to commit perjury of his scientific work and was forbidden to see his family and friends. Finally he became blind in 1637 and died in 1642.

What I have tried to make clear from the brief life histories of these two great scientists is that the scientific environment which was prevalent around these scientists could hardly be classified as congenial for the development of science. Not all of our young scientists can be a Copernicus or a Galileo, who would continue to search and express the scientific truth in spite of the danger of persecution. Our young scientists need encouragement for new hypotheses and theories rather than of suppression of new ideas.

After analysing the development of environment and the necessity of a congenial environment one naturally comes to the practical question i.e. what steps can be taken to achieve this congenial environment. I may be repeating myself on this point but I would like to mention again that long and serious efforts are needed to create a congenial environment in our laboratories and institutions. Some steps which can be helpful in creating healthy environment are briefly discussed below :

1. *Association of young scientists with more than one scientist :* Normally young scientists, during their period of training are attached to only one scientist. However, there are some institutions where a young scientist has the opportunity of working with more than one scientist during his period of training. In such cases the young scientist picks up the skill and experience of all the scientists he works with. At the end of his training, he is better equipped to handle his profession as compared with the young scientist who has received the skill and experience of only one scientist.

2. *Collaboration in research project :* Young scientists, being ordinary human beings, watch their teachers very closely. Side by side working of the concerned scientists make the young scientist realize the significance of his work.

This creates enthusiasm in the mind of the young scientist. He is able to discuss his research problems more freely. Since the concerned scientist is also actively participating in the same or a similar research project, he will be able to supply better guidance to the young scientist. To say that brilliant young scientists can be trained only by scientists, who themselves are actively engaged in research, is not far from the truth.

3. *Frequent seminars and discussions :* The knowledge of science has increased so much that the more one knows, the more one realizes how little he knows. It is very difficult to read or teach in detail, any branch of any subject. We can safely say that we have reached the age of specialization in this 20th century. Though indispensibility of specialization cannot be ruled out, it would not be healthy to induce specialization at an early stage of development of the young scientists. Frequent seminars and discussions on different subjects will expose the young scientist to different subjects or different aspects of his subject, and thus, widen the horizon of his knowledge. Moreover, during such seminars, discussion over existing controversies will provoke the young scientist's interest in such topics, and he is likely to get involved in such controversies. Only when one is involved in such controversies will one try to find answers which in scientific research can be termed as the revealation of the truth.

4. *Emphasis on the basic concepts of the subject :* The deep understanding of the basic concepts of the subject is a pre-requisite for any deeper understanding, or any fruitful or significant research in the subject. Though the necessity of teaching facts about any subject cannot be under-estimated, a greater emphasis should be placed for exposing the young scientist to the basic concepts of his subject.

5. *Creation of sense of originality, self dependence and patience in the young scientists :* A student lacking originality, patience and self dependence can hardly be trained into a brilliant young scientist. Frequent guidance and spoon feeding are not differentiated properly. It is not uncommon to encounter a young scientist, who after doing one experiment comes to a standstill until he is told the details

of the next experiment by his concerned teacher. Such spoon feeding will never allow the young scientists to develop their sense of creative thinking, originality and self-reliance.

6. *Social obligation of the young scientist :* It is very essential that the young scientist should realize his obligations to soceity. The society which provides him training has the equal right to demand his services for the betterment of society. If young scientists become aware of their social obligations we can hope that the sense of responsibility will also creep into their minds. This will teach the young scientist the purpose of his training and actually, the purpose of his life.

A Perspective of University Education

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The purpose of university education at the under-graduate level is to familiarize the student with the major goals, problems, and fundamental bases of a discipline rather than to attempt to train a specialist. At the post-graduate level, the aim is to provide the capable student with the opportunity and facilities to extend his mastery of a subject matter field as well as to develop his faculties for critical thinking and originality in the search for knowledge and truth. Such objectives in the Agricultural Universities would provide, scientific leadership needed to serve agriculture in the state, specialists in various branches, extension workers and good teachers for schools and colleges. To successfully achieve these ideals, the curriculum has to be planned in the right way. It is intended here to have a perspective of curriculum at the university level to bring out the lacunae in our system of education and to suggest the measures to improve and modify it according to the needs.

Field-covering approach : Out of the two major approaches namely the field covering approach and functional approach, the former is mainly followed in the Indian universities for the consutruction of biology curriculum. This approach attempts at surveying the complete archieves of the field and studying the fundamentals upon which are built the

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later studies leading to mastery in a field. Today, this approach faces the most serious difficulty which it never encountered before. With the advance of science, new ideas are made available and these in turn percolate in our courses making them more and more bulky day by day. But the idea of deleting the older material from the courses runs counter to the still existing notion that the basic elements of science should always be retained. The question of what is really basic has, however, seldom been considered. The time now seems ripe when we should select the data which is more fundamental especially in relation to agriculture. While doing so, the caution should, however, be taken to keep the true spirit of the subject alive by retaining those fundamental principles upon which its future development depends. Courses should be basic in nature, emphasizing principles, and designed to prepare the student to develop critical faculties in evaluating ideas and in solving problems.

Knowledge of certain courses is essential for every student of biology. Statistics and calculus are indispensible in solving mathematical problems in the biological research. These are also necessary for research workers to read, write, and interpret the technical articles. Those universities, which have not so far introduced these subjects in their curricula, are urged to do so. Two more subjects, biochemistry and genetics, have an increasing influence on many disciplines or biology. The former is not only essential for understanding of all the chemical manifestations of animal and plant metabolism but has also a great bearing on other fields of biology. The latter holds and will continue to hold a key position in agricultural research until, of course, the chemically synthesized varieties are made available. The understanding of the genetic principles had contributed a lot towards the improvement of old varieties and the production of new ones. Any agricultural research without the background of genetics and biochemistry would be similar to the treatment of a disease by some quack without the knowledge of human physiology. This necessitates the compulsory teaching of these subjects both at the undergraduate and post-graduate levels.

The courses in the curriculum should be well-balanced. They should neither be too brief nor too extensive, making the teacher either very slow or very fast to cover the courses.

A link and sequence should be maintained not only between different courses but also within the same one. Duplications and repetitions should be avoided as far as possible. Students should be required to get through the preliminary courses before they take up the advanced courses.

Laboratory and functional approach : To create a scientific mind among the students, it is essential that science should be taught as a method of thinking and acting to explore nature rather than an encyclopedic learning of discrete facts. In our universities relatively less attention is given to the laboratory. Moreover, the results are generally told to the students before the start of the experiments. Such experiments do not deserve to be called experiments in the true sense of the word and are no more than visual-education devices whereby the students visualize the phenomena and gain facility in the manipulation of certain material and apparatus. Steps should be taken to make the laboratory work more lively and scientific by setting up working experiments. As the students have an inborn urge for activity, they should be encouraged to perform the experiments, record and analyse the data, and finally deduce the results themselves, of course, under guidance of the teacher. Whenever possible the laboratory courses should be separated from the theory courses so that separate and more attention may be given to the former.

Today a progressive science teacher wants a modification of the curriculum making it more practical and functional. It has been experienced that an average student who knows the anatomy of the rat fully well, is incapable of advising the people on the eradication of rats when he goes to his village. Similarly a student after attending biochemistry courses knows little about the balanced diet of a person. The courses should be so oriented that the knowledge may also find its transfer to the daily living of the students. The laboratory and functional approach of education will stimulate the young scientist to develop scientific thinking in solving problems.

Seminars and assignments : For critical thinking in the minds of the students, the seminars and discussions occupy a significant place in teaching of biological sciences. During discussions and seminars, where students are active partici-

pants, new ideas are brought in and the understanding of the subject is much more certain as compared to mere recitation. In the curricula, seminars should be made compulsory at the post-graduate level. All seminars should be so planned and arranged that a particular portion of the subject is covered in a systematic way. Such planning would facilitate the student not only in understanding the subject more thoroughly but also would help them in getting an overall view of the subject. In addition to these seminars arranged by the staff of various departments, I would suggest that we encourage the advanced post-graduate students to hold annual seminars in various fields, where the entire programme is arranged by the students themselves. Such seminars are sure to create scientific leadership among the students and will train them in successfully arranging scientific gatherings later on.

To help the students in developing the power of selecting and writing the material, 'assignments' should be made a part of the curriculum. This would also facilitate them in learning the method of locating references taking down notes from the research journals and compiling them. This should be done at the post-graduate level. At the under-graduate level, where the number of the students is very large, assignments fail to serve the purpose as the students are liable to copy from one another.

Counselling and advisory committees : In the present age the development of science has been so rapid that no single discipline can be kept in a water tight compartment. Even the most recent discipline like genetics has established inter-relations with ecology, psychology, medicine and statistics etc. In these circumstances, therefore, the introduction of the system of advisory committee with one major and two or more minor advisors would be more effective in meeting the full needs of the student. This system has already been introduced at the Punjab Agricultural University. It may, however, be pointed out that the advisory committee generally meets the student only at the time of signing the research synopsis and submitting the thesis. This tendency needs to be changed. The members of the advisory committee should take active part in the formation of the curriculum for the student and meet him more frequently to assess his progress and to chalk out his future plans. Such an approach

will facilitate the release of creative energies and their channelization in the right direction.

Conclusion : No curriculum, howsoever carefully it might have been planned, can be of any use until and unless it is sincerely followed by the teachers. Well qualified and hard working teachers with a brilliant academic record will be an asset for the successful implementation of the curriculum. Their devotion to the profession together with dialectical approach is an essence in making the subject more functional. However, a teacher should be given as much teaching load as can easily be handled. To enable him to brush up previous knowledge and keep up with the latest researches, refresher courses in various subjects should be arranged.

The success of both the undergraduate instruction and study at the post-graduate level is measured by the quality of students trained and by their achievements in the fields of their specialization. To have this success, let us take up the noble cause of teaching biology to our students with devotion.

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Development of Leadership among Post-Graduate Students

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If we are to vastly improve our institutions, one of the pre-requisites will be to inculcate the spirit of scientific research into our students.

Scientific research : Each generation of research scholars has had to build upon the work of its predecessors—correcting errors when possible, filling in gaps, and gradually constructing a body of concepts that are more useful in solving problems than the guess work of laymen. To meet the demands of high calibred better-prepared research workers, graduate schools in Agricultural Universities should raise admittance standards and develop extensive educational programmes and instructional materials to prepare students for research (Van Dalen, 1962).

In science, intelligence well above average is necessary, although other indicators are : curiosity, open-mindedness, questioning originality, independence of judgement and humour. It is the characteristic of an effective scientist that he will work hardest on problems of his own choosing and will withdraw from tasks set for him if it seems necessary in the interest of autonomy. It is also characteristic that he is more likely to question casual authority than to accept it. The need for independence is one of the essential characteristics of a scientist. Much depends on the personality of the teacher and on the demands made upon him by his students. The characteristics of a teacher are : high intelligence, special aptitudes, deep knowledge of his own field, broad knowledge

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of related fields, knowledge of teaching techniques, flexibility, creativity and acceptance of student ideas. The teacher should have a capacity to encourage specific qualities of the gifted and channel them into worthwhile learning experiences. He must understand their characteristics and know how to encourage them to assume responsibility and take initiative. The teachers should be guides, counsellors, friends, guardians and they should hold up to their students firm standards of competence in scholarship as well as in behaviour. The teacher should increase his own competence in science by consistent reading of scientific literature, by attending meetings of scientific societies, or by engaging in research projects. These experiences help to extend the teacher's background knowledge of subject-matter and bring him up-to-date. A teacher should also keep himself informed on new developments in his field of study through reading professional literature, attending professional meetings, exchanging ideas with fellow teachers. He should continuously search for better ways of teaching (Brandwein *et al.* 1962; Hurd, 1961).

If the teachers remain ignorant of research studies, or resist applying the findings in the class-room, they can nullify the efforts of the most brilliant research workers. Developing a sincere interest in research also helps the teacher to establish better relationship with colleagues, administrators and parents (Van Dalen, 1962). Since mid-century, many exciting new developments have triggered enthusiasm for tackling fundamental problems that require highly imaginative concepts capable of explaining a great range of specific events or conditions. Better instructional procedures today are organised around problem-solving activities rather than mere memorization. One must also help students acquire skill in scientific methods of solving problems.

One of the most difficult phases of a graduate research project is the choice of a suitable problem. Those, who are experienced, know that research is often tedious, painfully slow, and rarely spectacular. They realize that the search for truth and the solution of important problems take a great deal of time and energy and the intensive application of logical thinking (Best, 1963).

Great discoveries rarely happen by accident. The research worker should be imaginative enough to sieze the

opportunity presented and to carry it through to a fruitful conclusion. Chance favours the prepared man (Best, 1963).

The researcher is a specialist rather than a generalist. Research is more than compiling data. It is based upon the application of rigorous logic to problems, starting with certain assumptions that give direction to data gathering. Then by the process of testing the hypothesis, generalizations are established. The concept of testing implies an objectivity that let the data lead where it will. Failure to substantiate the hypothesis in the testing process leads the researcher back to a modified hypothesis, which then becomes eligible for further testing and possible acceptance.

To teach the art of investigation, it is necessary to find a problem that probes the student's ability and energy. Stimulate the keen interest of the student so that he will keep reading and thinking until a problem occurs. The teacher's interest may lie in a special field in which he or she might have done some investigation. It is entirely practical to start students on specific problems in the teacher's field of interest. The most imaginative and independent students soon modify the original problem. The teacher and the student should use the community and the agriculture environment as the source of problems worthy of investigation. This is one of the objectives of sound education. The individual teacher finds his own means of teaching the art of investigation.

The source of problems : (i) The community is a logical source of day-to-day problems, (ii) Technological changes in agriculture and social developments are constantly bringing forth new problems and new opportunities for research, (iii) the graduate academic experience should stimulate the questioning attitude towards prevailing practices and effectively promote problem awareness. Class-room lectures, class discussions, seminar reports, and out-of-class exchanges of ideas with fellow students and professors will suggest many stimulating problems to be solved. Students who are fortunate enough to have graduate assistantships have an especially advantageous opportunity to profit from the stimulation of close professional relationships with faculty members and fellow assistants. Reading assignments in textbooks, special assignments, reports and term papers will suggest areas of needed research. Many publications

on the subject are rich sources for problem seekers, (iv) Consultation with the course instructor, advisor or major professor is helpful. Several writers have ridiculed the students who expect the advisor to assign a problem. Although research problems are not assigned, consultation with the more experienced faculty members is a desirable practice.

Most students feel insecure as they approach the choice of a research problem. They wonder if the problem they may have in mind is significant enough, feasible, and reasonably free of unknown hazards. To expect the beginner to arrive at the advisor's office with a completely acceptable problem is quite unrealistic. One of the most important functions of the research advisor is to help the student classify his thinking, achieve a sense of focus, and develop a manageable problem from one that may be vague and too complex.

Evaluating the problems : Before the proposed research problem can be considered appropriate, several searching questions should be raised. Only when those questions are answered in the affirmative can the problem be considered a good one :

(i) Is this the type of problem that can be effectively solved through the process of research ? (ii) Is the problem significant; Is an important principle involved ? (iii) Is the problem a new one ? Is the answer already available ? (iv) Is the problem feasible ? (a) Do I have the necessary competency to plan and carry out a study of this type. Do I know enough about this field to understand its significant aspects and to interpret my findings ? Am I skillful enough to develop, administer and interpret the necessary data-gathering devices and procedures ? Am I well-grounded in the necessary knowledge of statistical techniques ? (b) Are pertinent data accessible ? Are valid and reliable data gathering devices and procedures available ? (c) Will I have the necessary financial resources to carry out this study ? What will be the expense involved in data-gathering equipment, printing, test materials, travel and clerical help. If the project is an expensive one, what is the possibility of getting a grant from a philanthropic foundation or agency ? (d) Will I have enough time to complete the project ? Will there be time to devise the procedures, select the data-gathering

devices, gather and analyse the data, and complete the research report? (e) Will I have the courage and determination to pursue the study inspite of the difficulties and social hazards that may be involved? Will I be willing to work aggressively when data are difficult to gather and when others are reluctant to cooperate? Will I be willing to risk the criticism, suspicion, or even opposition that a delicate and controversial study may raise?

The agendum or research proposal : The preparation of an agendum or research proposal is an important step and provides a basis for evaluation of the project and gives the advisor a basis for assisting during the period of his direction. It also provides a systematic plan of procedure for the researcher to follow. Only with a well-designed agendum will a worthwhile research project result.

1. Parts of a research proposal *with a brief* explanation of each step. A statement of the problem, either in question form or as a declarative statement.

It may be appropriate here to formulate a major hypothesis and several minor hypotheses. A good hypothesis has several basic characteristics; it should be reasonable, consistent with known facts, stated in such a way that it can be tested as true or false and it should be as simple as possible.

Following these statements of hypothesis, possible conclusions may be suggested.

2. *The significance of the problem :* Careful formulation and presentation of the implications or possible applications of knowledge helps to give the project an urgency, justifying its worth.

3. *Definitions, assumptions and limitations :* The definition of terms, assumptions that the researcher makes and the restrictions and limitations that he recognizes, must be frankly stated. The recognition helps to focus attention on valid objection and helps to minimize the dangers of over generalizations.

4. *A resume of related literature :* A brief summary of

previous research and the writings of recognized experts provides evidence that the researcher is familiar with what is already known and what is unproven. Since effective research must be based upon past knowledge, this step would help preclude the duplication of what is known and provide helpful suggestions for future investigation.

5. *A careful and detailed analysis of proposed research procedures :* This part of the proposal identifies the entire research plan. It describes just what is to be done, how it will be done, what data will be needed, what data-gathering devices will be employed and an evaluation of their validity and reliability, how the source of data will be selected and how the data will be analyzed and conclusions reached.

6. *A time schedule :* A schedule should be prepared so that the researcher may budget his time and energy effectively. Dividing the project into parts and assigning dates for the completion of each part helps to systematize the project and minimize the natural tendency of procrastination.

Some phases of the problem cannot be started until other phases have been completed. Some parts of the final research report, such as the review of related literature can be completed and typed while waiting for the data to be gathered.

The progress report : From time to time the major professor or advisor may request a progress report indicating how well the project is progressing. This device also serves as a stimulus in helping the researcher to move systematically towards the goal of completing the project.

The first research project : Experience has indicated that one of the best ways to understand the method and process of research is to actually engage in research. The method may be learned by doing and thinking, under the careful supervision of the instructor at the beginning of the course in research.

The emphasis must necessarily be on the process rather than on the product and on its contribution to the advancement of knowledge.

Three elements : A student's first research project is usually in partial fulfilment for an advanced degree. Perhaps

more significant master's degree or a doctorate can be carried on under the direction of an advisor or major professor who is devoting his own interest to research in a major problem area. The studies of degree candidates thus should be directed toward certain restricted phases of the major problem, making possible long-term longitudinal studies. The emphasis should be placed upon the learning process, rather than on its actual contribution to education. It merely recognizes that the limitations of the first research project place emphasis on learning how, with the hope that subsequent investigations will progressively yield more significant contributions to the advancement of knowledge.

Three routine elements need solution before the teacher can embark on work with an individual student : the allocation of appropriate working space and suitable schedules; the order care and preparation of equipment; and the report of the work done. Wherever individual investigation is done, it is clear that the teacher or sponsor, cannot and indeed should not in the name of independent scholarship stand over the investigator's shoulder.

The teacher should be available for guidance and he should visit the laboratory to ask the student if he can be of help. The teachers should ask right questions and suggest further readings—but not tell the student the "right" way to do things.

Certain precautions are useful. It is useful for the sponsor to schedule regular conferences with individual students, perhaps once a week. The student should agree to comply with simple regulations; it is well for him to sign in and out of the laboratory to estimate whether appropriate time is being given for the investigation or whether he is spending more time than is consistent with his total school programme.

It is highly undesirable for the student to interrupt the teacher to seek equipment on the "spur of the moment". It is well to organize the work so that equipment can be secured on 1 or 2 days of the week during specified hours.

Other precautions are : to acquaint the student's parents with the nature of his investigation; to train the student in the use of new unfamiliar equipment and techniques; to

organize a laboratory squad to staff the storeroom, make equipment and materials available, keep the equipment in repair and general laboratories in order and to constitute and advisory committee for securing funds and equipment.

It is useful to help the student appraise his own progress. For this purpose, regular recording of observations and reporting of the progress of the work is helpful. Several methods to achieve this are :

1. The student should keep a notebook in which his daily work and observation, carefully dated (date and time) are recorded—in his/own style. This notebook should be kept at the place of work.
2. A monthly report to the teacher of progress of the work and a note about the reading done (with careful notation of bibliography) should be included.
3. A "seminar" to discuss the problems arising from the project.
4. The student should make a complete semiannual report in writing and if possible, an exhibit of the work should be constructed.
5. Annual assembly programme might be held at which student reports his work.
6. A journal should be developed in which research papers are published (Brandwein, *et al.* 1962).

The use of Reference Material : Practically all human knowledge can be found in books and libraries. Man builds upon the accumulated and recorded knowledge of the past. His constant adding to the vast store of knowledge makes possible progress in all areas of human endeavour.

Graduate students must find their own references. Few graduate students, however, and not all faculty members, have an adequate familiarity with the library and its many resources for the effective search for specialized knowledge. Extensive use of the library and thorough investigation of related literature is essential in preparing graduate term papers, seminar reports and in planning and carrying out the kind of searching involved in special field problems, thesis and dissertations. The search for reference material is time consuming but a fruitful phase of the graduate

programme. A familiarity with the literate in any problem helps the student to discover what is already known and what others have attempted to find out and what methods have been promising or disappointing, and what problems remain to be solved. Knowing how to use the library effectively should receive primary emphasis in the graduate programme. To know what sources to use, what sources are available, where and how to find them will save many hours of aimless activity.

Interpretation of data : The analysis and interpretation of data represents the application of deductive and inductive logic to the research process. The data are classified by division into subgroups, and then put back together in such a way that hypotheses may be verified or rejected; the final result is new principles and generalizations.

The process of classification, sorting and tabulation of data are important parts of the research process and decreases sources of error.

The statistical analysis of data : Statistics is the mathematical process of gathering, organizing, analyzing and interpreting numberical data, and is one of the basic phases of the research process.

Statistics is the servant, not the master of logic; a means, not an end of research. Unless basic assumptions are valid, the right data carefully gathered, recorded and tabulated and the analysis and interpretation are logical, statistics alone can make no contribution in the search for truth.

The research report : The research report is expected to follow the conventional pattern and form used in academic circles. The style of writing should be clear, concise and completely objective. Of course, the highest standards of correct usage are expected and careful proof-reading is necessary before the final report is submitted.

The use of tables and figures may help to make the measuring of the data clear. They should be presented in proper mechanical form and should be carefully designed to present an accurate and undistorted picture.

Evaluation of another research's report helps the student to develop competency in his research and reporting skills.

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The Concept of "Hypothesis" in the Field of Research

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Science begins with the observation of selected parts of nature and certain mental activities might, in the broad sense, be called methods of science. The scientific methods of research may be spoken of as any mode of investigation by which scientific or other impartial and systematic knowledge is acquired. Accordingly this is achieved by two principal types, the technical methods and logical methods. The technical method involves manipulating the phenomena under investigation, measuring them with precision and determining the conditions under which they occur, so as to examine them in a satisfactory manner. The logical method, however, involves reasoning about the phenomena investigated and drawing inferences from the conditions under which they occur, so as to interpret them as accurately as possible. This involves certain mental activity and one of the processes in sequence of events of investigation is the derivation of hypothesis which is very closely linked to the individual involved.

Even the most restricted portions of the real world are too complex to be comprehended in complete and exact detail by human effort. For one thing, under increasingly refined observation it is found that it is impossible to neglect interaction with the rest of the universe. As a consequence, it is necessary to ignore most of the actual features of an event under study and to abstract from the real situation, certain aspects which together make up an idealized version of the real event. This idealization, if successful, provides a useful

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approximation of the real situation, or rather to certain parts of the real situation.

It is convenient to break the idealization into a number of parts for separate treatment, i.e. to analyze the problem, and to synthesize from relatively simple parts which construct an approximation to a real situation. Closely related to the above steps is the practice of simplification. These simplifications may be such that they could approximate, possibly though not necessarily, existing real situations or they may be quite impossbile of actual realization.

The trial of an idea concerning any phenomena or sequence of events in nature and the connection of the observation leads to hypothesis. In fact this stage begins during the observational one. Hypotheses differ in their subtlety and consequently in the obscurity of their origin. A simple one may be a mere generalizaton of the observations. A more complex hypothesis may postulate connection between events, or an elaborate chain of causes and effect. Analogy is a very powerful tool in the construction of hypothesis, but with it imagination is of utmost importance. People differ enormously in their power to construct useful hypotheses, and it is here that true genius shows itself. The possibility of constructing hypotheses rests on the assumption that there is some order in nature. This is not the same as the assumption that all parts of nature are ordered. The fact is that many parts of nature have been found to have an approximate order, but many other parts have so far defied the attack of scientists e.g. mastery over the weather. The usual view point is that this is a difference of degree only, but if a given set of phenomena is sufficiently complicated, it is certainly possible that it is beyond human power to unravel it within the foreseeable future.

If two different hypotheses fit the desired facts and if one is clearly simpler than the other, it is usually customary to accept the simpler one until further evidence causes its rejection. It has often been questioned whether this is justifiable but it is always done, and it is certainly hard to justify the opposite course. But it is not true that a simple hypothesis can always be found.

The most important feature about a hypothesis is that it

is more a trial idea, a tentative suggestion concerning the nature of things. Until it has been tested, it should not be confused with a law. Unfortunately in many fields, especially on the border line of science, hypotheses are often accepted without adequate tests. Plausibility is not a substitute for evidence, however, great may be the emotion. Plausible hypotheses are merely set down as facts without further ado.

In many cases, hypotheses are so simple and their consequence so obvious that it becomes possible to test them directly. New observations on selected aspects of nature may be made, or more often an experiment can be performed for the test. There is no clear cut difference between an experiment and a simple observation, but ordinarily in an experiment the observer interferes to some extent with nature and creates conditions or events favourable to his purpose. Furthermore, if the hypothesis under consideration is a simple generalization, it may be sufficient to test it by looking for more examples, seeing whether or not the generalization holds for them. However, if the original basis for the hypothesis was wrong, the unfavourable instances may so outweight the favourable ones as to make it reasonable to believe that the earlier agreement was a matter of pure chance.

Successful prediction is usually considered a stronger support for a hypothesis than the explanation of an equal quantity of observation known to the creator of the hypothesis at the time of its creation. In other words, a hypothesis not only should fit the facts which brought about its creation but should also be compatible with the rest of the body of the science. This is a very hard condition to satisfy because of the scope and complexity of modern science. It is laborious to ascertain whether a given hypothesis is in fact compatible with every thing already known. But if the investigator knows that his hypothesis is going to be tested in the near future by experiments based on its predicted consequences, he will probably be much more careful to see if it does fit the known facts.

Few scientists would claim that any hypothesis, however, extensively tested, was a statement of a absolute, universal truth. It is much more likely to be good, perhaps even excellent, approximation for a finite range of circumstances, the boundaries of which are not well demarcated. As

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Few scientists would claim that any hypothesis, however, extensively tested, was a statement of a absolute, universal truth. It is much more likely to be good, perhaps even excellent, approximation for a finite range of circumstances, the boundaries of which are not well demarcated. As

further studies are made, a more accurate or more widely applicable generalization will almost surely replace.

As already stated, the derivation of hypotheses have no boundaries or direction for their origin. Both fundamental and applied research can yield ideas leading to the construction of a working hypothesis. Its application in practice may foster a unity between both applied and basic research but only extensive experimentation can prove its validity and acceptance.

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Emphasis on Students' Own Choice

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In the teaching-learning process, cooperation is required of both the partners i.e. the teacher and the taught. Ideas of the teacher thrust on the taught cannot result into effective teaching, and to achieve the same, willingness as well as actively receptive mind of the taught are absolutely necessary. The choice of the student as to what he should learn is important, but the decision as such, should be arrived at after a thorough consideration of all pros and cons which are highlighted as under :

Psychology of choice : An accepted view among many psychologists is that younger years of age are particularly influential in determining personality traits such as attitude, motivation and goal. Two most important factors which influence all individuals are heridity and environment. Which of them has greater effect is any body's conclusion from the observations that a great many of the outstanding men in particular field have appeared from a particular region or a country; or that a tremendous concentration of a particular talent has occured at certain localities for a century or two and then vanished from there. We may, however, deduce that people of all nations and faiths do possess enormous potentialities which have to be explored or improved by proper education. In order to accomplish this, George R. Price quotes Professor Pressey to have listed five conditions as important : (1) opportunity and encouragement provided by family or friends, (2) superior guidance and instructions from early age (3) frequent practice from an early age, (4) association with competent adults in the same field, and (5) stimulus of strong success experiences.

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Basis of the choice : Student's choice of their career should be broadly based on consideration of the following points :

1. Educational objectives.
2. Aptitude of a student.
3. Country's immediate and future needs.

With regard to the educational objectives, various levels of education from beginning to completion should be recognised. A student should exercise his choice at each level.

1. Secondary school level. At this stage students should be exposed to the environments which would influence the selection of their likely career i.e. students planning to take up agriculture should be exposed here to the agricultural conditions of the region and the country.
2. At the undergraduate level, a young man is developing as a technologist or a professional. His mind should be rightly channelled so that besides technical competency, he should also be imbued with his moral duties and code of ethics in the profession. In addition it may also be desirable to expose the student at this stage to some degree of specialization which could help him to choose a particular subject for post-graduate studies.
3. At the post-graduate level, the student is making into a specialist. At this stage, according to the faculties inherent in him, he has to choose teaching, research or other allied fields within the framework of his narrow specialization.

At each of these levels of education, the students' own aptitude will play a dominant role. He would be persuaded by his own instincts and talents to choose his line, through a path prepared by advices of parents and teachers. A variety of professional aptitude tests are available, which may be employed by the educational institutions. These tests are primarily used to select applicants for admission to professional colleges, but the extent to which these are useful in predicting one's ultimate professional success is not too well-known. Furthermore, it is generally recognised that as a criterion for admission, these tests are useful as a

supplement rather than as a substitute for the grades in the qualifying examinations.

The country's immediate and future needs are important considerations on which should depend the student's choice. This is necessary not only from patriotic or national point of view but also there is greater scope and recognition of one's work if it is in keeping with the needs of the country.

Facilities to make choice : Teachers guide the destiny of their pupil and the nation. In order to effectively discharge this high *responsibility, every teacher should* remember the words of Sidney Sugerman, "Teach the young people how to think and what to think". A teacher's role is thus of an immense importance. If the instructions received by students are thought provoking, they stimulate the thinking process. Personal qualities of the teacher can lead and inspire the student. Furthermore, teachers may emphasize the importance and scope of their subjects which will greatly facilitate the students to select their field of specialization. The system of tutorial groups or the allotment of advisors is being used in many institutions. Their proper functioning is undoubtedly of great value as a teacher can meet frequently with a small body of his wards. Functions of these meetings should be akin to the family meetings where free and frank exchange of views are possible. The students can thus be guided to select the courses they need and also to make a choice of their subjects for specialization. In such tutorial groups meetings or in special seminars arranged by the institution, the students should be apprised of the departmental and other developmental plans in the country. This background knowledge will go a long way to help students to make right choice.

John Hersey has said, "The most important unsolved problem in education is discovering and releasing the maximum potential of each child....If we discover what children have in them early enough, we will have more than enough of everything". Teachers should make efforts to study the students' leaning and liking. The basic requirement of all the students is intelligence, common sense and scholastic ability. The degree to which this is processed by each individual may be judged. A belief that those who had led a rural life and had been closely associated with

farming in earlier days would become better agriculturists or veterinarians has been observed to be only partly true. Some youngmen from urban areas when given the necessary state of mind, aptitude and determination of objective have excelled over those coming from the rural areas. What is required, is that a student must receive proper facilities, opportunities and environments and that by contact with competent people from various walks of life, he accomplishes a solid background on which he should base his choice for a prospective career.

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The Psychology of Learning

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With advancement of knowledge in all fields of education and the increasing complexities of life brought about because of the impact of knowledge and its application in its different forms, people are now looking more and more towards psychology for finding solution to problems, which go beyond the scope of that knowledge.

Psychology developed rapidly as a science as soon as it was accepted as a science of conciousness. By the close of the last century, people had well recognised the individual differences between man and man, which resulted in the differences in learning experience among the individuals undergoing the same type of learning processes. With the coming of Binet in 1904, saw the beginning of the application of psychology into the field of education with any degree of seriousness. He classified students according to their intelligence, and it became possible to separate out the ones who were incapable of being benefited by the traditional form of education. Since that humble beginning, psychology stands today as an independent science spreading its tentacles to many fields. The latest to be added to its fold is human engineering. There is more stress and strain on the nervous system because of the growing complexity of machines and abnormal internal and external conditions. Supersonic speeds, tremendous heights, and weightlessness reached by man have all given greater importance to the study of this aspect of psychology.

To a teacher involved in the higher education, the importance of psychology can be found immediately when he has to pick out the right candidates out of the tremendous numbers

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of applying for entrance into a faculty. Here is the problem of guidance. Once the students are selected, the teacher searches better methods to help him impart the desired knowledge to the desired goals in a more effective manner. Here comes the application of the theories of learning. The importance of 'adhyayain', 'manan' and 'chintan' in proper order and sequence is already known to all of us. The importance of each of them at different levels with different subjects has to be studied. The quality of our nervous system to gain knowledge above the one acquired through usual learning processes, has been well-recognized by the psychologists and extensively studied. To what extent it can be developed in a given individual needs to be studied. Every teacher would then be interested to find out the change he has brought about in his student through the educational experience. He would, of course, need to keep in mind the different areas he explores and the ways and means to reach these areas. This would require the application of better and better methods of testing.

The problem of a really good teacher does not end here. Often, a really good teacher has to face much more complex problems. Some of them relate to the problems of adjustment in his students : either within themselves or their jobs or schools or home or society. Some of them may be much beyond his own scope. This involves the problem of guidance, which may be educational, vocational or personal.

Even if we believe in the traditional concepts of knowledge and its assessment, the broad classification of the factors responsible for what a student achieves are :

(i) The student, i.e. his intellectual capacities, interests, aptitudes, etc.

(ii) The staff—who are trying to impart knowledge or information, with the help of equipment at their disposal.

(iii) The environment in which the student has to live, either spontaneous and healthy for the acquisition of the knowledge or repulsive prohibitive.

(iv) The attitude of the student towards work and his work habits, which if immature and undeveloped, will hamper the acquisition of the desired knowledge.

(v) Motivation.

It will not be difficult for any teacher to find the importance of each of these factors. Condition (i) draws our attention towards the individual differences between one man and the other in his intellectual capacities, interests and aptitudes. Other things being equal, the more intelligent a student, the greater the achievement.

I need to lay little emphasis on the second factor, i.e. the staff and equipment, the importance of which is already known to us all.

The healthy and encouraging environment gives due recognition to the individuality of a student. The home, the institution and the society, all have to make their contribution in building up this environment.

The contribution made by the fourth factor, i.e., the work habits of students is also very important. It is not an uncommon experience for most of us to see many of our not-so-bright boys showing better results in examinations by their sheer hard work and labour, sometimes to surprise us. If to all this motivation are added, such prospects as a bright future associated with better results, the effect on the achievement could be better still. Every factor explained here has its own limitations which often is dependent on other factors as well. For example, an intellectually inferior student may fail to compete with a superior body in spite of his extra dilligence and the superiority of other factors. An ideal situation would be when all five factors are strong in a student, which, unfortunately, happens only rarely.

A careful and experienced teacher usually knows enough of psychological problems to realize what abilities and attributes should be expected of his students. Through close and intimate contact with the students, a correct appraisal of their capacities is possible. However, when this is not possible, the teacher likes the assistance of the phychologists. As against carefully planned, reliable and valid tests, the teachers' methods are in most cases crude, highly subjective and biased, and may not give him the correct picture of his students. Under such conditions, psychological tests would be better tools.

While constructing a test, a psychologist always keeps in mind three important criteria for his tests; objectivity, reliability and validity. An objective test is one which when prepared with a definite objective in mind, will give the same results when assessed by different individuals. A test is reliable if it is capable of giving almost similar results when administered a second or a third time. A test is valid if it is capable of assessing an attribute for which it has been prepared or designed, to a remarkably high degree. Another important quality of a psychological test is that standardized scores, or norms as they are called, have definite meaning, in context with a larger group of candidates, which is not to be found in the marks based on traditional form of examination.

In the application of the above principles, particularly when the demands of the students of a higher standard are concerned, the qualifications of a psychologist, his experience in dealing with the type of problem in hand, and the care and interest he takes in analysing the whole situation in assessing, are all very important. It may be possible that, in spite of his experience and care, he is ignorant of the new situation or problem put before him. In this case, he will need to put much effort carefully studying the subject under an experienced teacher. He may need to help the teacher himself in preparing the test under his own critical supervision. But under all conditions such a test, before it is finally accepted, has to be tried again and again, and undesirable items eliminated or substituted with more appropriate items. A test prepared in an haphazard manner cannot be expected to bring out any results. This is true at all stages of psychological testing, it may be a selection, a placement or a simple assessment of the students' capacities for diagnostic purposes or for any other use.

A psychologist is also found helpful to the teachers and students of higher classes in the adjustment of students' problems, whether they be social or personal or within the home or the institution or the society. Because of the problem of mal-adjustment it is not surprising that quite a number of bright boys and girls have spoiled their careers.

Finally, a true psychologist is fully aware of the limitations under which he has to work. Instead of being involved in needless controversy, he like a scientist, carefully involves himself with the problem until he reaches the desired end.

Class-room Teaching Methods

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Elements of teaching : All of the many things involved in teaching are just part of three major elements : (1) Something to be learned, (2) the action by which the student learns and (3) the degree of the students receptivity for learning experience. When a teacher becomes familiar with these three things, he can put all other details of thought or action about teaching into a clear and orderly concept and understanding of the teaching process.

Supporting concepts :

(1) A definite objective is the focal point for everything in a properly planned lesson.
(2) A psychologically correct learning experience is required for every lesson objective.
(3) The quantity and accuracy of a student's learning depend on how receptive he is to the learning experience and this depends on his adjustment, motivation and readiness.

When someone first observes a teacher in action he will probably get the impression that teaching is a very complicated process which includes numerous different kinds of knowledge and ability. That is true, of course, and because of that the development of skill in teaching takes time, study and much practice. There is no short cut to proficiency.

This does not mean that the path of becoming a good teacher need be confusing or difficult to follow. Everything that goes in the process of teaching belongs in one of the

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FORMAL EDUCATION AND ITS PURPOSES

AN OBJECTIVE

An act of teaching affects behaviour most when it is directed toward producing.

A SPECIFICALLY DEFINED RESULT

Consisting of one of the concepts, abilities, symbols, feelings, or habits which make up the subject matter of the curriculum.

A LEARNING EXPERIENCE

The specifically defined result is obtained when a student goes through.

A PARTICULAR LEARNING EXPERIENCE REQUIRED BY THAT DESIRED RESULT

The teaching procedures are : Showing, discussing, applying evaluating, drilling and guiding.

RECEPTIVENESS FOR LEARNING

The student's receptivity to the learning situation depends on :

HIS ADJUSTMENT
HIS MOTIVATION
CURIOSITY
Interests
Discipline for learning
Driving goals
HIS READINESS
Maturity
Previous learning
Sensory abilities.

three categories listed in Fig. 1.

There are some routine activities often referred to as "house keeping", which have little or nothing to do with teaching, like calling a roll or sometimes collecting money for certain activities etc.

Discussion of the supporting concepts : (1) A definite objective is the focal point for everything in a properly planned lesson.

The term objective has a very simple meaning. It is something to be reached or attained. Here is a class-room example. A teacher wants his students to understand that the autumn season brings about changes in trees, flowers and other plants. This is a concept. He hopes the students will acquire it or in other words, develop an understanding of it. His objective will have been reached when the students comprehend the fact that changes in plants are brought about by the autumn season.

An objective in teaching is always one of single or small subdivision of curriculum selected for learning at a particular time. It is that item of information or understanding, or skill which is to be the next learning business of the class. Three kinds of objectives are dominant in the curriculum and almost every lesson deals with one or more of these concepts, skills and habits.

The simpliest way to state an objective is to write out the concept statement. Following this the objective could be explained, described and defined in various ways.

(2) A psychologically correct learning experience is required for every lesson objective.

The most efficient way to approach any objective is usually the simplext and most direct path. The nature of path depends on the objective. Leaving out possible complication for the moment, let us return to the example of objective cited earlier.

The objective set by the teacher was to have his students understand that autumn brings about changes in plant life.

To attain this understanding, students will have to acquire the concept of the processes and objectives involved, and the way the changes occur in relation to the season. Concepts are acquired through seeing the objects or the processes and through discussion until they became clear. When they are clear the person understands that particular thing.

Learning is always a psychological process. Students are complex psychological beings. They are capable of engaging in several kinds of psychological processes. For example, there are seeing, hearing, tasting, talking, memorizing, remembering, imagining, practising etc. Which one or ones should be drawn into operation for any given objective ? This is determined by the nature of the objective. The teacher has very little choice. If the students are to learn what something looks like, they have to see it. If the objective is an odour they have to smell it. If it is general concept they have to remember all of the specific items that make it up and think about them, until they find the general or common element in all of them. If it is a skill they have to practise it, using particular motion and muscles required by that skill. The individual utilizes his various psychological process almost automatically when he is faced with something he wants to learn. Without an excellent teacher, he may be rather inefficient in doing this but each object or situation we face in life tends to excite the psychological processes within the person which naturally cope with that situation. In the interest of both accurate and efficient learning the teacher must know which processes are required for any or every objective. Then he must plan a set of experiences for the student in which these processes are activated, and in which the student takes in the true characteristics of the objective he is intended to learn.

The two real tests of the artistry of a teacher are found in these two steps. First, can a teacher clearly and definitely identify the concept, or skill, or habit that he is trying to teach ? Second, can he plan ways of getting the students to go through the right learning processes for that objective, and do it efficiently and thoroughly ? These are simple ideas, but to carry them out under the many conditions of teaching requires much knowledge of both the contents of the curriculum and the learning processes of people. The artistry then consists of laying out important objectives in the

right form, for learning and obtaining all the materials needed, to enable the students to perceive and work with the objective, and guiding their experience with the materials, so that the objectives are reached quickly and soundly.

(3) The quantity and accuracy of a student learning depends on how receptive he is to the learning experience and this depends on his adjustment, motivation and readiness.

Whether a student learns from one of these experiences depends on whether he opens up his senses, so to speak, and lets it "in". If he does we say he is receptive. The more receptive he is the more he will learn.

This is our third aspect of teaching. It is not part of the teaching processes as such, but it is very important to it. When a student is completely unreceptive to a learning situation, nothing a teacher does seem to get through him and produce learning. On the other hand when a student is "all eyes and ears" so to speak, he learns very rapidly with relatively little help from the teacher.

Whether a student studies hard and learns well in school is not just a simple matter of whether he will pay attention or not. On getting down to the facts of the causes, there are two somewhat opposed approaches to this problem. One is that the student can apply himself if he will and, therefore, through good disciplinary practices which strengthen his will and character, he can be trained to apply himself. The other is that each person has a set of behaviour patterns and tendencies which have been from his past experience. He is powerless to set them aside; therefore, not to be blamed for his behaviour. He is a victim of his environment and experience. What he does is determined by his past and not the present.

Since these things are a product of past learning they can be altered through new learning or other kinds of guidance, but they cannot be overcome on the spur of the moment. The teacher cannot ignore them or set them aside. It is important to recognize that the real genius of human being is his capacity to build and to rebuild his life. He can bring his behaviour under the control of his intellect, transcend

the world that he finds around him and create a new one in the image of his own vision. To guide a student to these possibilities is not only a noble calling, but a very demanding one. A thorough knowledge of the factors that determine a person's receptivity to new things is indispensable in such a task.

It must be recognized that there are three conditions in a student which affect his response to a lesson.

One condition is the student's stage of adjustment. If he is free from worry and tensions over conflicts he is usually interested in many new things and is able to turn his attention to them without reservation.

Another condition is student's motivation, that is, what he is interested in, and what he wants to do. Motives are rather deeply entrenched in past learning. They include our concepts and values, and the goals to which we have given ourselves. The person who has found consistent value in going to school and in studying will be motivated to give his attention to his lessons more than will another who has not found such value in education.

A third condition is the student's readiness for a new activity. It is rather easy to move into a new activity when one has the necessary background for it, but it is quite difficult to do so otherwise.

However, there will always be individual differences in receptivity for learning and therefore, teacher should do everything he can within reasons to help his students keep well enough adjusted to learn, keep interested and motivated to learn and have the essential previous learning and background for each new object which is laid out for learning.

Teaching aids : Probably no other vital institution in Indian life has changed more in the last decade or so, both in objectives and in methods of securing objectives, than has our educational systems. The change has been in values, in the subjects studied, in means of support, in organisation, in administration, in teaching techniques and in conception of correct class-room procedures to place a student properly in his niche as a young citizen in a democracy.

As is the concept of education changing, so are changing the methods of education and even the teacher and the student relationship.

From schools which were teacher dominated and text book-centred, the modern class-room is becoming more and more student centred, teacher directed and community vitalized. Moving away from text-books as the heart and soul of a student's class-room activity, he is also a significant citizen of the world in which he lives. Text-book today is but one of many side streets opening into the wide avenue of learning.

Other side streets leading into this avenue today, the side streets through which the student studies, take many forms: visual and audio aids; the radio television; picture shows and sound recorders; all are used extensively for class-room purposes in some of the more modern countries. There is no reason why some of these aids cannot be used in this country as well. In addition to these aids the students should be encouraged to use library more extensively. Here, his knowledge if made up-to-date, not only from some of the more technical books or periodicals, but also from the magazines, daily papers and comic books frequently contain technical or popular articles on many aspects of sciences including agricultural science. In this respect even the study trips help a great deal, as such trips allow him to observe, study draw and take pictures of the objects he is interested in. With the help of different aids a student of today is exposed to more reading material and knowledge in a week than a student of a century ago ever saw in a year. Each of these aids to a text-book carries with it some activity. The information he gets is always understandable, as it is always thoughtfully acquired. Study today for a modern student, therefore, can be concrete, real and vital.

Study for production : In schools of yesterday, study was almost entirely for reproduction. Perfect reproduction meant that study preceding the class had been thorough. Today, the student reproduces in a more limited number of fields, and he reproduces less in any one field. He studies by stating the meaning by putting material into his own words. Because he is studying for a purpose such as trying to find the answer to questions, or produce something he is going to

use, he is conscious of memorizing very little. Here some of the psychological factors that tend to operate are "wide association", "recency" in using the studied material again and the factor of "enjoyment" in learning". What a student studies is closely related to what he already knows. Associative books are not lacking. Material in use today is again in use tomorrow and in days which follow. Thus factors of both recency and frequency enter into his recall and recognition.

Teacher and taught contact and communication : In order to help achieve the above objectives of the present day education, it is necessary that there be a more intimate and informal contact between the teacher and the student. The teacher should be easily available and easily accessible. Since no one text-book is rigidly followed and the amount of knowledge presented to students from various sources described above may at times be beyond their power of comprehension, it may even cause confusion. I feel, to relieve this pressure, as frequently as possible, a part of the study period may be specifically set aside as discussion or question-answer periods. The teacher may also ask students to present seminars, write term papers, prepare exhaustive literature reviews, discuss certain scientific papers appearing in literature or give them course assignments. Of course, time element should always be considered in making such assignments; too little to do for the time allowed is almost as bad as too much. The last exercises will not only keep the students out of mischief but will provide an opportunity for the teacher to judge the different capabilities and the potentialities of the individual students. These exercises can also be used to measure the intellect, initiative and independence of the students.

Following are some of the essential points of the pupil-teacher interaction :

1. Maintaining and providing proper physical conditions.
2. Maintaining good order.
3. Developing a pleasing, yet thorough technique of questioning.
4. Organizing and directing the activity for each day's work.
5. Helping individual student, yet maintaining a group effort.

6. Testing the effectiveness of what is being done.
7. Developing background material so that what happens is meaningful to each student.
8. Setting the stage for the next work.

Course content : Today, knowledge for its own sake is rarely, if ever, an objective of class-room study. Cowper's injunction might guide us:

Knowledge and wisdom, far from being one,
have off times no connection.
Knowledge develops in heads replete,
with thoughts of other men.
Wisdom in minds attentive to their own.

The above says in Poets' words; knowledge is insignificant until it is meaningful. Teacher has the responsibility of making materials that are 'meaningless' to the students, 'valuable', as indicated by the experience of maturity. Failing this, the teacher has taught nothing, or at the most little. The teacher directs, selects to a great extent, initiates, encourages, and clarifies for the student the learning, considered most desirable.

Although most of the schools and colleges use detailed courses of study as guides, some set forth explicitly the objectives of each part of the curriculum. Some use uniform *examination procedures that seem to fore-ordain what* teachers ought to teach. Even then individual teacher can and does exercise decisive choice, at literally hundreds of crucial points. What a place of learning is trying to teach is largely a summation of what individual teachers have selected as important.

Now it is obvious that within the limits of curriculum a teacher is going to teach what he feels is important. Therefore, to me it seems more important how he teaches :

The teacher entering a new position, or even the one who has been in the same position for many years, cannot wait until the first day of school is upon him before planning his work. It is said that person who plans *carefully is usually the master of a situation.* Teacher will not have time to plan in detail all of the class work he is going to teach during

the year or the trimester. However, before the start of a session, a teacher should prepare in detail, every class assignment for the first week, outline the work for each lecture, laboratory period, references, and other details. The first week is the heavy week of the year, and a complete working plan for every class will be a big help.

How a teacher looks : Lastly it may not be in-appropriate to mention a little about correlation of looks of a teacher to his success. Students are observant. The teacher who is careful of his appearance will find that satisfaction accrue both in personal and financial way. The latter is due to the fact that it is much easier to see the ability and excellence in a well attired and a well groomed performer than in one who is careless of personal appearance. At one time a good superintendent of schools commented in the course of his address, "Every teacher can afford to dress becomingly as administrative heads will usually see enough extra-merit in his work and because of his appearance will make school pay for his clothes in the long run.

Clean, well fitting clothes, well-polished shoes, variety of costumes and appropriate jewellery (in case of women), appropriate glasses (if worn), and nice looking teeth are marks of successful teachers. Not that these things in themselves bring success, but the correlation is high between these items and success.

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Approaches to Sciences Teaching in Indian Universities

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I have been asked to discuss some of my own views on teaching methods in science courses, especially courses in Biology. I do so, however, with some trepidation as teaching in the professional sense is a field in which I have only recently been initiated. Before coming to this country last fall I was engaged in full time research as a biologist in Canada, and my main contacts with the teaching profession were through my friends and colleagues who are teachers in Universities and at the secondary level. However, I have gained some general impressions, through some osmotic process, from such contacts and from my associations with ex-students in the research laboratory. And, from one point of view, a lack of history in teaching may be an advantage because it reduces the chance of lingering prejudices which might have been left over from earlier teaching experiences. Assuming, then, that a lack of extensive earlier teaching experience has some positive advantages, I would like to suggest that consideration be given to three major approaches to the teaching of science, particularly biological science, in Universities in India. I am aware that a few institutions may already have gone some way toward adopting some of these ideas. These suggestions are intended primarily for consideration of those Institutions which so far have not done so.

Laboratory practicals in science courses their importance : "Science", in the broadest sense of the word, is a

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method of approaching problems, an approach which we call the "scientific method". Although we often have a tendency to think of it as such, "Science" is not merely a collection of facts (data) per se, but more important how we collect the data. It is an attitude of mind. If, for example, we wish to know how long it will take for an iron ball to fall from a certain point to the ground we can calculate the time by using an equation, and if the equation is valid we can predict the unknown time. However, implict we are in all such calculations, it is a fact that at any time, we can verify the result by actual observation, and indeed the method of calculation was itself initially worked out on the basis of observations.

The basic dependence upon observation in the sciences should, in my view, be reflected in courses in scientific subjects. In addition to the data and facts to be presented in such a course, the students should be given opportunities during the course to observe how the data were obtained. This is the reason for laboratory practicals in Science courses. A course, say, in biology is only a course in abstract concepts unless the students are given an opportunity to observe animals and plants and see how they function. I realize that this may seem tediously obvious to many, but I emphasize it at this time because I have in the past come across courses in scientific subjects, in India and abroad, which offered no direct observations of the materials discussed.

Admittedly, it is difficult sometimes to include relevant practicals in certain courses. But it is rarely impossible. Lack of a practical can be attributed to either of several causes :

(1) the nature of the subject makes a practical difficult;
(2) the cost of apparatus for the practical is too great, or apparatus is not available.
(3) the instructor considers a practical too difficult or time consuming compared with lecturing.

In the case of (1) it is very rare indeed when something relevant to the subject cannot be included. Preserved specimens are always available for a course in Marine Biology at an Inland University and even in the worst seasons of the year, a class in Ecology can make observations in an indoor terrarium, study temperature and humidity measuring

devices, or can carry out some basic exercises in population statistics. Often (2) is a very real factor to contend with, particularly in the developing countries. However, there are a great many ingenious ways of devising various types of apparatus from readily available materials, and in fact several publications exist which are designed expressly for the purpose of aiding improvisation of laboratory apparatus in Science courses (e.g. "Source Book for Science Teaching" UNESCO). There is scarcely any item in experimental biology laboratory which cannot somehow be improvised incrude, but nevertheless workable form. In the monthly magazine "Scientific American" the section entitled "The Amateur Scientist" is a very commendable source of instruction for many kinds of basic apparatus and exercises. Difficulty (3) should be cleared up easily if the instructor is convinced of the necessity of including practicals in his course.

There is one field in particular in which laboratory practicals are especially important : experimental biology (e.g. Physiology). In India there is a great need now for rapid development of practicals in this field. In the past, here and abroad, the accent has traditionally been on the more descriptive approach to Biology, but now Biological Science has become very much an experimental science. A Biology Department which offers no laboratory exercises in experimental biology is stagnant. There is no doubt, in my view, that the most rapid rate of development of biological science in India in the immediate future will be in experimental fields. This trend has been recognized by the Punjab Agricultural University, and my reason for coming here was to establish teaching and research laboratories and facilities in Animal Physiology. During the past trimester the Department of Zoology-Entomology offered, at the M.Sc. level, its first Physiology courses with an integrated theoretical and laboratory program, and next year the number of such courses will be doubled while the laboratory space devoted entirely to experimental exercises will be more than doubled.

There are in this country a number of commercial firms able to supply good experimental apparatus. To develop experimental biology it will be necessary to establish more adequately equipped laboratories to give students practical experience with experimental exercises. I should also like to add at this point that inherent with all experimental

apparatus is the need for adequate maintenance, and no apparatus should ever be purchased without it, at the same time, ensuring that replacement parts and regular maintenance are available.

In equipping a laboratory for practicals in biological subjects a most important consideration is the level at which the subject is to be taught. It is useless to spend several thousand rupees on a spectrophotometer for a first course in general physiology; on the other hand, such a course must offer exercises covering the basic concepts taught in the course. Although it is sometimes easier to include certain exercises merely because the apparatus is available, such exercises may provide very little enlightenment to the student unless they demonstrate basic principles and idea in the course.

Depending again on the level of the course, the organization of the practical work may take various forms. I would say that in lower level courses in experimental biology the students generally do short exercises requiring one or two practical periods in more advanced (or more specialized) courses the tendency is to give groups of students one, or at the most two, more extensive problems upon which to work in the laboratory.

In those practicals offering numerous one-period exercises, these should, ideally, coincide in time with teaching of the relevant theory. This is often difficult to arrange, however, particularly when there is a shortage of apparatus necessitating that the students do the exercises in rotation. It is probably best to aim at having all students in the practicals do the same exercises at the same time, but, again this is not always possible to attain. We may not be able to arrive at these various optima, but we can at least strive to do so.

The relative importance of the practical in a biology course, compared with the theoretical part must be left to the discretion of the instructor (or his superior). Generally, I would say that at least one third of the final mark should be given for the practical. Often, assigning a mark for work done in the practical is a matter of some difficulty. Note-books, which always should be kept by each student showing his methods, observations and conclusions (in that order)

can be marked, but this in itself is far from being a fool-proof method of assessing the student's laboratory work. Tests on the practical work can be given, either written or actual "working" (practical) tests. Also the teacher can make a subjective (but often fairly accurate) assessment of the student. Probably the best course is a combination of all these methods of assessment, due mainly to the limitations of anyone of them alone.

In summary, a course in a scientific subject which does not include a fairly extensive practical gives the student no real first hand experience with the subject. The laboratory practical helps the student to relate theory to actual practice, and without it, the student will find difficult later on in putting the theory to use. Also, special attention should now be given to the production of a good foundation of specialists in the experimental biological sciences who can be the future teachers and developers of these fields in India.

Tutorials and seminars : New trends from an old idea : Someone once said that people like to learn, but they resent the feeling of being taught. Students seem to prefer getting involved in a subject (if they have any interest in it at all), and usually this requires a more personal relationship between student and teacher than is possible in the formal lecture situation. Such a relationship has been recognized, of course, for many years in old institutions such as Cambridge and Oxford. However, over the years it has been almost exclusively the practice in most teaching institutions to maintain a rigid quality between teacher and the taught, especially at the undergraduate level. On theoretical grounds, this quality is not reasonable because, as every good teacher knows teaching someone else involves a good deal of learning and re-learning on the part of the teacher. It seems more reasonable to say that learning is a spectrum, a matter of degree, and if this is so should not the teachers and students do their learning together ? If there is more contact between students and teachers, one might expect more cross-stimulation and this will result in a faster learning rate, more inspiration, and greater retention of ideas and concepts through greater degree of imprinting.

This is not to detract from the values of the lecture situation. Many students (and I am one) can get a great deal from a

formal lecture. And where the class is large (say, over 50) some lecturing is necessary. However, some students can absorb more and are stimulated more by closer contacts and more personal attention on the part of the teacher. Moreover, I believe that almost all students actually prefer to have a closer contact with the teacher (the reverse is not always true of the teachers).

These facts are becoming increasingly more recognized in Universities and Colleges in North America and this is especially obvious in new institutions. Apparently it is easier for new institutions to adopt new approaches than for old established institutions to do so. There is a growing feeling of alienation on the part of students in the large North American Universities, and this is partly responsible for the major re-examination of the approaches to teaching now underway there. In Canada, there is now great activity in establishing new teaching institutions, and Universities and Colleges are springing up everywhere. In my home province, British Columbia, four Universities now exist, whereas a few years ago, there was only one. They are experimenting with new approaches to teaching, and in all cases the trend is toward *increasing the amount of personal contact between teacher and students*, at the undergraduate level as well as at the graduate level. In one institution, where the student-body numbers less than 1,000 more courses are given entirely as tutorials, with up to 10 or 12 students per class. On the other hand, the new Simon Fraser University in Vancouver, which opened its doors two years ago, has about 4,000 students and it operates on the trimester system. They are solving their "Size V. S. Contact" problem in the following way : in the large classes as many as several hundred students at a time are given lectures (say once a week) by an eminent authority in the field, either live, or by the use of films or closed-circuit television; after the lecture, the students are taken into tutorial sessions in small groups, which are handled by post-graduate students acting as teaching assistants, and in these sessions they go over the lecture material in detail. At the new Trent University in Ontario, the accent is on tutorials and seminars, and not long ago I learned that the Head of the Department of Zoology there is giving only one lecture per week. In the long established University of British Columbia (enrolment 17,000) an experiment with a pilot group of students is now

being initiated which, if successful, will eventually mean complete revisal of the approach to the undergraduate curriculum in the general arts and sciences; it will involve the breaking up of large classes into smaller sections for closer contact with instructors.

Tutorials can be handled in several different ways, depending upon the instructor, and to illustrate this I shall outline what we have done, and what we hope to do, in the new physiology courses at the Punjab Agricultural University. In the first course (comparative animal physiology), last trimester, three periods had been allotted to theory per week (i.e. 3 lectures per week). There were approximately 40 students in the course. We decided to give two lectures per week, and one tutorial. In this case, the lectures and the tutorial were almost independent of each other. The lectures were planned and given in the usual way using the several available textbooks for reference. In the tutorials, however, readings were assigned a week in advance from a very compact and explicit little book in the "Foundations of Modern Biology" series, and then the material and basic concepts in the assigned reading were afterward discussed in the tutorial. Thus, in a sense, the students were given two simultaneous courses in physiology, covering the same basic material but in different ways. In the three months, the students learn a quite a bit of basic physiology. Later we gave them questionaire in which we solicited their anonymous opinions regarding tutorials/lectures; they were almost unanimous in preferring tutorials to lectures (two or three had no preference) and many of them wanted even more discussion than they had.

Next year, in a General Physiology course, we shall try a slightly different approach that will be somewhat easier to handle. We intend to give two lectures per week, and the third period in the week will be a tutorial in which we shall go over the lecture material presented during the first two periods. That class is expected to number about 40 students, and each week two of us will take two sections of 10 students each in tutorials. Thus, instead of giving more new material in a third lecture each week, that time will be spent recapitulating the material from the previous two lectures.

Although the form of the tutorial depends upon the

teacher, it is advisable that he avoid the temptation to lecture in the tutorial. His role is to guide the students into learning through their own discussions. There is no doubt that the ability to conduct a successful tutorial is an art which must be carefully cultivated, and it comes easier to some than to others.

Seminars are also coming into more general use, especially in teaching at the post-graduate level, and undoubtedly there are situations where the seminar approach is most suitable. I feel, however, that often the seminar is merely another lecture situation, with the students individually substituting (often poorly) for the professional lecturer. I would not consider the seminar a substitute for the tutorial. On the other hand, the seminar has the advantage of giving the student practice in presenting ideas to an audience, even it may occur only once or twice during a course.

In summary, then I would like to urge that every consideration be given to increasing the amount of teaching contact between teacher and students. The teacher should get involved in the learning process. Wherever possible the merits of the tutorial methods should be seriously considered.

Graduate students as instructors : Many Universities in this country which offer graduate studies have a built-in resource which is not being utilized to the fullest extent—the graduate students themselves.

In the first section of this paper, I emphasized the need to have laboratory practicals associated with courses in scientific subjects. Such laboratory sessions require adequate supervision, but in India at present there appears to be a chronic shortage of adequately trained supporting personnel. I refer, for example, to persons with a Bachelor's degree, who do not have sufficient experience and training to qualify as professorial staff, but who nevertheless would be of great value in assisting in laboratory practicals. Many persons who have obtained the Bachelor's degree in a Science are not willing to accept permanent employment at that level, and, commendably, they wish to continue their studies. How then can trained supporting personnel be obtained ? In their efforts to obtain qualified supporting people, for example for laboratory assisting, it would be worthwhile for Univer-

sities in this country to give more consideration to the method by which most North American Universities have largely solved this problem. In many Institutions there (in fact, probably in most of them) every graduate student is expected to spend a portion of his time each week assisting (demonstrating) in undergraduate teaching laboratories. For this he receives some remuneration, although it is very little. This work is generally considered to be an integral part of the training of every graduate student. The benefits of this arrangement are three fold—(1) The professor giving the course receives reasonably well-qualified assistance in giving his laboratory practical; (2) the students taking the practical receive more assistance than would be the case if the laboratory assistant had no training, or if they had no assistant at all; and (3) the student assistant himself gains a considerable amount of experience in teaching the subject, and (even more important) he learns much more about the subject than would be the case had he not tried to teach it to others. Many graduate students enter the teaching profession upon leaving their formal studies and their previous laboratory teaching experience stands them in good stead. And I would say there is no better way to assess one's own knowledge of a subject than to try and teach it to others.

The tutorial approach which I have outlined in the previous section is effective in proportion to the number of instructors available to handle tutorial teaching sessions. In the graduate students of any institution, there is a considerable potential teaching staff. I have already discussed how the new Simon Fraser University in Canada is using graduate students, apparently successfully, as tutorial instructors in undergraduate courses following lectures to large classes by authorities in the respective fields. Utilization of graduate students in India as tutorial instructors should be given every consideration. Again, I wish to stress the fact that the individual graduate student gains a great deal more knowledge of the subject by teaching it to others, and some teaching duties should be an integral part of the training of every graduate student.

Some might argue that utilization of graduate students as teacher is a case of "the blind leading the blind". But a graduate student obviously can be expected to know more about an undergraduate course previously taken than an

undergraduate student currently taking the course (otherwise why is he a graduate student ?) and as such he is in a position to help the undergraduate. Further, by being required to teach it he will have to learn more. I have distinct recollections of many of the graduate laboratory instructors or demonstrators, who taught me when I was making mistakes in my undergraduate practicals, and I recall that they knew far more about the subject than I did at the time. It seems to me that this system in North America would not have continued in such widespread usage for so long unless it had been found of value, and I see no valid reason why similar system could not profitably be used in India.

Also if it is argued that this would be impossible to implement due to the already heavy load of the graduate student, I would suggest the probability that the graduate student is then too heavily loaded with formal course work and is being "force-fed" to his deteriment. It is not a matter of reducing his overall load, but of changing the emphasis.

In summary, I would urge that serious consideration be given in the Universities of this country to the utilization of graduate students as teaching assistants in laboratory practicals and tutorials, simultaneously with, and as an integral part of their post-graduate training for the dual purpose of increasing the number of qualified supporting personnel in undergraduate teaching and to upgrade the graduate student's knowledge of his subject.

Summary : In this paper I have urged that the fullest consideration be given by Universities and Colleges in India to (1) increasing the opportunities for practical observations by students in scientific subjects, and especially in the experimental biological sciences; (2) adoption of the tutorial method of teaching, at the undergraduate and graduate levels, wherever possible and (3) use of graduate students as teaching assistants as an integral part of their training in undergraduate laboratory praçticals and tutorial sessions.

Teaching Methods in Clinical Subjects

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We shall here discuss the teaching methods as applicable to the efficient teaching of clinical subjects.

What are clinical subjects : Clinical subjects are those which have a direct bearing on the patients which are brought for treatment to the clinic. All the patients brought to the hospital may be suffering from various diseases and according to the systems involved we may group them as skin diseases; digestive, respiratory, circulatory, urinogenital, nervous diseases and so on; but broadly speaking they are conveniently categoriged as diseases Medicinal, Surgical and Gynaecological. The subjects of Medicine, Surgery and Gynaecology (including obstetrics) are, thus, designated as clinical subjects and teaching in these subjects has essentially to be more patient-oriented rather than class room-oriented.

Why more stress on the patients : Detailed accounts of different diseases are given in the books and these are all decidedly.useful. But various facts about a disease are to be memorised for retention which is a dry and cumbersome process. Patients, on the other hand, are symbols of diseases, and when properly understood and explained, can speak volumes, which leave deep and unshakable impressions on the minds of the students. Moreover, the discussions on the patients are interesting and absorbing and leave very little scope for the students to be unattentive. Furthermore, clinical work by the students, gives them the urgently required contact with all types of animals in health and disease

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and creates in them the much needed confidence in handling and treating them. All that is required is the proper organization of the programme in such a way that maximum benefit is derived from the patients both for the students as well as for the patients themselves and it is this aspect of the problem which we will presently discuss.

Organization of the teaching programme in clinical subjects : The teaching programme in clinical subjects has to be organized according to the availability of the number of patients coming to a teaching institution. Some institutions are very lucky and attract a large number of patients. In such institutions, the students are also lucky and can get adequate and useful clinical practice. In other institutions the number of patients may be meagre and in such places some special efforts are needed to obtain clinical material for making up the deficiency.

Programme when the number of cases is adequate : Those of us who had the good fortune of visiting the Punjab Veterinary College, Lahore, cannot forget, the very large number of daily cases coming to that institution. It ran into well over two to three hundred cases every day and the students got an extensive practice on all types of cases during the period of their stay at the college. It may not be possible for us to bring all the Veterinary Colleges of the country to that standard from the hospital practice point of view, but certainly much can be done to improve the existing conditions at most Colleges. Recently some dynamic changes have been introduced in our own clinic at the hospital attached to the College of Veterinary Medicine at Hissar, which have lead to a substantial improvement in the teaching of the clinical subjects as well as the increased utility of the hospital for the public and it is on the basis of these favourable results that I feel bold, in a humble way, to offer some suggestions for our friends in the other institutions.

(i) *Time to be spent by the students in the clinic* : Clinical subjects are mostly in the curriculum of the final year class. The students of this class must spend all their morning time in the hospital. This is the time when a large number of patients are brought to the hospital. The bodies, as well as the minds, of the students are fresh, active and receptive and best use should be made of this time to hammer maximum

practical information into the students memory and to get good physical work out of them.

(ii) *Dress for the students working in the clinic :* Working in the clinic with the animals is not a clean job. Animals become nervous and pass urine and faeces quite often during the act of examination and treatment. Blood, pus and other dirty material may often spoil the clothes of the workers. If the students are dressed in tight and costly clothes, they will all along hesitate to handle the patients effectively. On the other hand, if they wear some cheap overalls and trousers specially designed for the purpose, they will work without any difficulty. The students must also be equipped with their own thermometers and stethoscopes. Both these instruments *should be handy and readily available with all students* so they will use them cautiously and avoid a lot of breakage in thermometers. Their own stethoscopes will become their life-long companions for veterinary practice.

(iii) *Students staff ratio in clinic :* All the students detailed for duty in the clinic should be divided into three groups; one for medicinal cases, the other for surgical and the third for gynaecological cases. These assignments should continue for one week so that they can follow up the progress of the cases assigned to them. These three groups should be further split up in small batches of 6-8 students in such a way that one such batch is under the charge of one teacher. The *staff students ratio in the clinic should be 1:6 or 1:8 but in no* case it should go beyond 1:10. Number of students less than 6 will not be able to handle, secure, examine and treat the cases in large animals properly and the number of students beyond 10 may become too unwidely for the teacher.

(iv) *Teachers job in the clinic :* As soon as a teacher gets a particular batch of students assigned to him, he should get them to a patient and start explaining about the case. General examinations including taking of history, registration (signalment), habitus, taking of pulse, temperature, respiration, etc., should be entrusted to different students. Special examinations of the different systems needed, should then be initiated and explained and ultimately clinical laboratory examinations for blood, faeces, urine, milk are conducted to complete the investigations. Tentative diagnosis with differentiating points from the other similar conditions should be

discussed and the line of treatment chalked out. Necessary treatment should then be given to the patient who may be allowed to go with instructions for feeding and further treatment.

No doubt, some owners feel distressed with handling of their patients by so many students but if they are properly tackled and good treatment given to their patients, they will not mind the inconvenience. It is necessary for all teaching institutions to keep an adequate stock of antibiotics and the other latest drugs so that the owners are not bothered to purchase such medicines from the bazar at their own cost. This facility will make them unmindful of the incovenience which their patients have to suffer and will make the institution popular which will attract a large number of patients in the best interest of the students.

The staff for the clinical work must be adequate, experienced, efficient and satisfied. Clinical teaching is a tough and hazarduous job for a veterinarian. Only that teacher would be able to arouse the students' interest in this work who has confidence in handling cases and who feels interested in the work himself.

Wherever necessary, photographs of interesting cases, and recording of abnormal sounds in the heart and lungs may be carried out for demonstration purposes for the whole class.

(v) *Students job in the clinic* : In order to make the students work with a sense of responsibility, cases should be assigned to the batches of the students. Each batch should conduct general, special and specific examination and record them on the forms designed for the purpose. Recording of these cases on the forms is very essential. It keeps a student busy and forces him to take observations for the maintenance of these records. Treatment given to the patient along with the daily progress should also be noted so that the records are complete. These detailed case records can serve as a very useful data for compiling information on different diseases. Nursing and feeding of the indoor cases should also be the job of the students and they should be clearly told that their attitude towards the care and handling of their patients will be given

due consideration in evaluating their class performance.

Students in the beginning may not be in a position to perform some injections (intravenous, intrathecal, etc.) for treatment in certain cases and in order to avoid objections of the owners, such injections may be given by members of the staff. Students should be given practice in these injections on some animals maintained at the college for this purpose. When they get a free hand, they can be entrusted with the treatment of all the cases.

(vi) *Ambulatory clinical work :* It is easy to treat cases at the institutions where all arrangements are ideal and necessary facilities exist. Many animals are not in a position to come to the hospital or some cases may be in far off places. Training of the students to treat cases under village conditions, is, therefore, very necessary. For this purpose, organisation of ambulatory clinical work is essential. An ambulatory van, capable of carrying a batch of 4-6 students with necessary medicines and equipment with a teacher, should be available with every teaching institution. Regular visits on fixed days should be made to some of the villages where the people are interested and these contacts must be continued. Serious cases which cannot attend the hospital should be given treatment at the farmer's place. This type of regular contact with the villagers pays a rich dividend to a teaching institution because the students learn to handle serious cases and also the treatment of other cases under field conditions. The teacher accompanying the students, becomes conversant with the problems of the farmers in the villages which can be taken up and worked out in the institution. Similarly, results of research work which are of interest to the farmers, can be communicated to them.

(vii) *Use of summer vacation for augmenting studies in clinical subjects :* Vacations are a valuable period for clinical teaching. The students and staff are free from the burdens of learning and teaching of the other subjects and if clinical teaching in summer vacations is organised in such a way that every student must cover a certain percentage of attendance in the clinic during summer vacations, it will go a long way in giving additional practice to the students.

(viii) *Holding of seminars to discuss clinical cases :*

There is no dearth of interesting cases in good institutions. All such cases should be discussed in the specially organised seminars where the whole class and all the teachers of the clinical subjects should thrash out all aspects of such cases. The failures in diagnosis and treatment, when encountered, should be readily accepted and the discussions fruitfully utilized for the enhancement of knowledge.

Programme where the number of cases is inadequate : The teaching institutions which are not lucky to get a good number of cases will have to depend mostly on ambulatory clinical work and training of the students during summer vacations at some veterinary hospitals which attract a large number of cases. Both these methods are expensive, associated with incovenience and still not very satisfactory. Efforts should, therefore, be made and, ways and means devised, to attract sufficient number of cases to the college hospitals, to give good practice in teaching of clinical subjects to the students. So long as this is not achieved, great stress has to be laid on the ambulatory clinic and summer vacation programme.

Dr. R. P. S. Tyagi, Dean College of Veterinary Science, P.A.U., Hissar, gave many valuable suggestions.

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Developing Reasoning Power of Post-Graduate Students

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The change from school to college is considered to be a big jump but the change from undergraduate to a post-graduate student is bigger still. From a student he becomes a scientist. He has to develop reasoning power so as to find explanations for the observations recorded and on the basis of those, put forth new theories.

To be a scientist, one is required first to develop a scientific attitude which according to Newman (1961) is defined as below :

"It is unsentimental, unsuperstitious and undogmatic. It pledges no irrational loyalities, is free of the bias of property owners and wears neither school tie nor political badge. It is as distant from the crowd as from the cloister. It is not the censor of any faith so long as that faith is not the censor of the normal appetites and reasonable hopes of the mass of men. It is curious, sympathetic open, tentative and hospitable to change".

He should be sincere and a searcher of truth.

These are the important aspects of the outlook of a scientist which the teacher has to first develop in himself and then see that they are also taken up by his students.

Invention is not made overnight. The famous case is

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that of the sudden discovery of Archimedes. Had he not the intelligence and the scientific outlook which he developed over long years, the discovery would not have been possible?

Discoveries are made step by step over a long period. "Everything of importance has been said before by somebody who did not discover it. But the hunger for horses is as great as the hunger for scape-goats; and as some innocent men are hanged lest murder go unpunished, some undeserving men are rewarded lest discovery remain anonymous"—Newman (1961). Some important points in post-graduate training are as follows :

1. Develop confidence in your work and do not under rate your discoveries. "Henery Poincare and Hendrik Lorentz, among others, approached the theory of Relativity but lacked the courage to make their thoughts explicit"—Newman (1961).
2. To make the students think independently,avoid giving cut and dry answers to their questions rather encourage them to think of some answers, even if they are wrong. Then, without an authoritative attitude, explain the correct reply scientifically and also tell why their answers were wrong.
3. The desire to create and discover new things should be encouraged. The problem for research should be carefully assigned. The student should not be told simply to work on a certain project, rather he should be given guidance to choose that project, from which he thinks he will obtain some good information. We should not produce data-takers and paper-makers.
4. Simple figures mean nothing unless they are read : Saying that treatment "A" was the best and treatment "F" the worst is not the end of the research rather it is the beginning because reasoning follows later. Why it has happened so, needs always to be investigated.
5. It is not necessary to follow the authority of big scientists. If the data proves something different than that proven by well known scientists, the facts should not be ignored. Internal respiration by plants remained undiscovered for sometime because of this fallacy.

6. Do not be misled by the percentage alone. In a weedicide trial 500 per cent increase was recorded by the application of weed control methods while under similar conditions differences were not more than 5 per cent. In one case there was heavy growth of weed while the other field was free from it. Weed competition Index was suggested for correct reporting of weedicide trials.
7. Experience perhaps is the best teacher. We can learn quicker by trying to do something than by merely being told how (Landis 1954). The students may be given assignments for drawing conclusions from the given data.
8. Create an atmosphere of social relationship with the young scientist that he feels he is an important organ of the machinery working for a particular project and he is under obligation to do his duty for finding new things.,

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Scope and Role of Specialization at Undergraduate and Post-graduate levels

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Introduction : This topic should be viewed with a clear understanding of the purpose of agricultural education. Is agricultural education a training to prepare the student in the art of agriculture, i.e. in the day-to-day operations in agriculture or is it a training to open the vision of the student to the many scientific facts that explain and regulate agriculture ?

General agricultural training versus specialization at undergraduate level : We in India are going through a period of revolutionary changes in agricultural production. Just as in transportation, where we have jet air travel side by side with bullock cart transportation, farming at the highest productive level is existing side by side with subsistence agriculture. In the early stages, the need for an agricultural worker was to be a jack of all trades so that he could be a multi-purpose advisor at a low level efficiency, to the farmer. As farming is becoming highly organised with great attention being paid to high quality seeds, adequate preparation of land, adequate use of fertilisers, adequate irrigation and timely pest control measures, the farmer has to obtain a higher level of aid from agricultural workers. This introduces the need for developing agricultural workers with a strong general training in all aspects of agriculture and some strengthening in a particular field.

Specialization at undergraduate and post-graduate levels : While there may not be serious argument in the need for

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specialization in agricultural training, there can be considerable differences of opinion on the extent of specialization both at the undergraduate and post-graduate levels. One cannot take a rigid attitude in this. The extent of specialization must develop depending upon circumstances. In a highly developed agricultural situation as it exists in United States, training at the undergraduate level involves considerable specialization in terms of agriculture, Dairy Science, Animal Science, Agricultural Economics, Horticulture, Agricultural Journalism etc. My opinion is that at the undergraduate level the branch of training at the present time should be just Agriculture (Crops and Fruit production), Animal Science, Veterinary Science. However, there can be variations depending upon peculiar circumstances existing in a certain region. For instance, Punjab and Himachal Pradesh are two States where an undergraduate training involving considerable specialization in Horticulture could be initiated.

Thus, at the undergraduate level a student has to be trained in various disciplines, giving him a strong basic training to analyse agricultural problems and plan ways of improving practices that can yield more. These disciplines are : Biology, Mathematics, Genetics, Biochemistry, Plant Pathology, Entomology, Plant Breeding, Soil Science, Agricultural Economics, Farm Management and Agricultural Extension. Similarly in Animal Science, training should include : Biology and Mathematics, Genetics, Biochemistry, Animal Nutrition, Animal Breeding, Animal Physiology, Animal Health, and Animal Management. Similarly, the Veterinary curriculum at the undergraduate level should include : Biology, Genetics, Biochemistry, Physiology, Bacteriology, Gynaecology, Parasitology, Pathology, Medicine, Surgery.

While a student should have some sound training in all these disciplines, there may be scope for developing a little additional emphasis on one or more of the applied disciplines at the undergraduate level, leaving it to the choice of the student as to what discipline he would choose. This is essentially an attempt to direct the student for further training after graduation.

At the post-graduate levels, i.e. M.Sc. and Ph.D. level, training is in one special discipline, in general agriculture,

Animal Science or in Veterinary Sciences. A person with post-graduate training fits into the classification of an expert in a particular discipline. As an expert, he must know more than the generally trained individual knows and must use the knowledge in that discipline, to advantage. His training is directed toward supplying information to the general worker in the field after gauging the need in the field of his particular discipline and then directing his analytical mind to face those problems to find suitable solutions i.e. at this level he becomes an Inquirer (Research worker). As agriculture developes, this person becomes a very important link for further growth in his field.

Conclusion : There is considerable scope for specialization at undergraduate and post-graduate levels in agricultural training. The success of the training programme depends upon directing the extent of this specialization to meet the needs of the economy. There ought to be a constant review of the extent of specialization and changes introduces at the appropriate time in the regions where such changes are necessary so that maximum benefit will accrue to agricultural production.

Education Leading to Development of Young Scientists

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Education is the acquisition of the art of utilization of knowledge. This is an art very difficult to impart. The experiment in teaching and advising the post-graduate students have led me to believe that many aspects of the scholarly efficiency is, at first contact, extremely perplexing to the young scholar. Approaching specialized study and research for the first time, the beginner frequently fails to understand what is expected of him and finds questions rising in his mind for which the answers are far from easy to obtain.

It is unfortunate that most of our post-graduate students seem to think of post-graduate programme as the unavoidable barrier which they must hurdle in their race for a higher degree. The degree may be necessary to get the student's advancement in his profession, it is a tangible badge of achievement for all to see and advise.

Is post-graduate work really different in kind from undergraduate work, or does it consist merely of additional courses and slightly more advanced instructions ? Is there something distinctive and special about the courses with higher numbers in the College catalogue ? Actually there are profund and the fundamental differences between the post-graduate programme and the undergraduate programme. In the College programme, in the undergraduate years, it is easy to see that a student could successfully complete his courses, receive his Bachelor's degree and

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become what one would recognize as a thoroughly cultured person, without ever having been in the strict sense of the word, a scholar. The scholar is not simply educated person or one with high academic ability, though the term is sometimes used loosely to indicate any person who is attending school. By definition, the scholar is a learned person, one with special competence in a particular branch of the world's knowledge. The post-graduate student is an apprentice in scholarship.

Post-graduate work introduces intensive study of a special field : By narrowing the area to be studied the student can dig deeper and acquire a greater understanding of details.

Post-graduate study characteristically involves research : Undergraduate work ordinarily consists in receiving facts and ideas that are already known. The post-graduate student on the other hand attempts to discover new truth.

In learning the vocation of the scholar, the post-graduate student must become familiar with the methods used in conducting sound research. The scholar's real purpose is to acquire knowledge not for himself but for mankind, by pushing back the boundaries of human ignorance. Schloarship means the search for new truth, even though the contribution of any one person can rarely be spectacular and can be arrived at only through painstaking labour. The individual scholar adds his bit to the world's discoveries by the slow accumulation of the small truths in many fields of our civilization.

The graduate student as an apprentice in scholarship : The student under the direction of an expert becomes acquainted with the spirit and method of research by serving a kind of apprenticeship. Frequent consultations between professor and student or master and apprentice help to correct the errors as well as to delineate various techniques of research, most fruitful in his particular field. The expert will also be familiar with the important mean and the outstanding research already accomplished in that field and consequently will draw the student's attention to it.

On the other hand, the post-graduate student is expected to attain the art of working independently. The course he

is advised to take will give him a solid background of the knowledge required to carry his pursuit. He should not expect a blueprint of his programme to be provided by his professors but should be able to acquire much of the necessary information through reading and observations.

Besides the above mentioned aspects of post-graduate programme, there are other aims of advanced education, training the mind of the student in learning thoroughly the technique and language of research. Since our country is short of good teachers, another purpose could be to provide a graduate student with specific training for that goal.

Summarizing the purpose of post-graduate education, the most common may be :

1. To advance human knowledge.
2. To train scholars for research work.
3. To prepare students for a profession, such as teaching, and
4. To offer one or more years of advanced instruction along the lines of the students' interests or special needs.

Post-Graduate Education in Veterinary Medicine

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"It has been said with truth that the real well-being of a profession depends on the vitality of its schools and their ability to educate their students in the broadest terms, for the tasks of their future profession." Post-graduate education forms an essential part of imparting education at the Veterinary and other professional colleges. Colleges without facilities for post-graduate studies cannot maintain the rapid progress and the standard which is desired from such institutions, especially in this era of rapid advancement. Research cannot be introduced on a sound basis in institutions which do not undertake post-graduate studies.

In the United States, in 1959-60, seven per cent of all Veterinary students were engaged in post-graduate studies. The trend of post-graduate studies is on the increase. In 1948, there were only 87 students in U.S. engaged in post-graduate studies as against 252 in 1958—an increase of 300 per cent in ten years' time. Recently the post-graduate education has received greater attention in India as well, especially with the start of Agricultural Universities in several states. The Punjab Agricultural University is the pioneer one to provide facilities up to Ph.D. level in most of the disciplines of Veterinary Medicine.

Post-graduate education in Veterinary Medicine is being imparted in basic as well as clinical subjects. Greater need is being felt to provide specialized training in clinical subjects to solve the enormous animal-disease problems facing this

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country. In India, so far, research and post-graduate teaching has been mainly undertaken in basic and preclinical subjects. The workers directly engaged in the problems of animal health and disease control have not been associating themselves with post-graduate studies and research. As a result of this not much attention was given to the field problems of livestock health. Those engaged in research on basic and preclinical subjects could hardly appreciate such problems.

In U.S.A. the veterinary medicine was given due priority from the very beginning. Advances in solving the problems related to cattle health brought about remarkable improvements in the livestock and cattle wealth. The clinical departments too are well-strengthened in that country. At the Ohio State University the number of faculty members in the departments of Veterinary Medicine alone is 34 as compared to 35 faculty members in all the rest of the departments, viz. Surgery, Pathology, Physiology-Pharmacology, Bacteriology, Parasitology and Anatomy.

There is a greater need for specialists in the clinical subjects especially that of Veterinary Medicine for research and teaching as well as for specialised hospital practice. Today, the field of knowledge is so vast and continuously expanding that it is impossible for an individual, no matter how able or well-informed one may be, to have specialization of diagnosing and treating all the various animal diseases in different species of animals. Development of highly skilled specialists would increase the general usefulness of veterinary medicine and hence the status of veterinary profession. By this the development of clinical veterinary medicine will be accelerated. It would provide means of training better qualified clincians for teaching in veterinary colleges. It would increase the quality and quantity of veterinary clinical research. Properly developed post-graduate clinical education could stimulate the advancement of clinical veterinary medicine to a great extent. It is generally believed that there is a demand for highly skilled clinical specialists in the following areas at the present time (Pritchard, 1962).

1. Large animal (cattle) medicine.
2. Poultry medicine.
3. Swine medicine.

4. Small animal medicine.
5. Equine medicine.
6. Laboratory animal medicine.
7. Camel medicine.

Large animal medicine : The specialists of this field would be required to undergo an advanced training in cattle disease problems such as : digestive, respiratory, reproductive, metabolic and infectious diseases and mastitis. Besides courses in cattle diseases the training programme should include advanced courses in cattle nutrition, management and economics as well as courses in preclinical subjects.

The diseases of sheep and goats and their control could also come under the domain of this speciality.

Poultry medicine : Advanced knowledge of poultry diseases and their control would be the basis of this specialization. Particular emphasis should be placed on respiratory and other infectious diseases, metabolic disorders and parasitic infections. Considerable training in diagnostic techniques would be desirable. Advanced courses in pre-clinical subjects and in poultry nutrition, breeding, management, and economics should also be offered. The course should be designed to prepare veterinarians for poultry practice and diagnostic laboratory work.

Swine medicine : The specialists of swine medicine should possess advanced knowledge of swine diseases and their control. Particular emphasis should be placed on digestive, respiratory, infectious, parastic and nutritional disease problems. Advanced courses in preclinicals, in swine nutrition, breeding, management and economics should also be included.

Small animal medicine : The basis of this specialization would be advanced knowledge and control of diseases of small animals, particularly of dogs and cats. Particular emphasis should be placed on digestive, respiratory, infectious, parasitic and metabolic diseases. Diseases of public health importance should form an essential part of this training. This is high time that measures to control diseases like rabies should be adopted.

Equine medicine : Advanced knowledge of equine diseases and their control would be the basis for this specialization. Particular emphasis should be laid on diseases of foals, parasitic infections, infectious diseases, lamenesses, diseases of reproduction and metabologic disorders.

Laboratory animal medicine : The basis for this specialization would be advanced knowledge in diseases of animals commonly used for research particularly mice, rats, guinea pigs, and rabbits etc. There should be advanced training in clinical laboratory medicine and diagnostic techniques.

Camel medicine : The basis of this specialization would be advanced knowledge of camel diseases and their control. This is a new field and needs a few veterinarians with specialization in the control of camel diseases.

Courses : Courses for post-graduate education in Veterinary Medicine should be so organised that the students can derive the maximum benefit out of them. Besides giving them courses in the major subject, emphasis should also be laid on the allied subjects. Courses in biochemistry, nutrition, genetics, statistics etc., should also be invariably recommended for students studying in any subject of Veterinary Medicine.

The post-graduate student cannot be expected to memorize the rapidly increasing quantity of factual information becoming available and the teaching should be so organized that his power of deductive reasoning be developed. A teacher who only expects students to memorize the information imparted in his lectures should find no place in a veterinary college.

Research problems : In India there is a vast scope for investigations in disease problems of livestock and poultry. Problems involving great economic and public-health importance should be given priority. Teachers should allot important disease problems to the students so that they can learn more about such diseases and could continue working on them, if necessary, even after graduation. This is the only way how specialized veterinarians in various fields could be available.

Employment : A post-graduate teacher is not only required to teach and produce graduates but also he is supposed to help them find suitable jobs. For sometime to come the teachers in Veterinary medicine would have no difficulty in arranging suitable jobs for their students. The specialists in Veterinary medicine would be required for research, teaching, and for specialized hospital practice. It is felt that veterinarians specialized in large animal medicine, avian medicine, and laboratory techniques can be posted at each district head-quarter for diagnosis and treatment of diseases of livestock in that district. Veterinarians specializing in laboratory animal medicine can be absorbed in research institutions and medical colleges maintaining laboratory animal colonies besides being absorbed in teaching and research sections of Veterinary colleges. Specialists in equine, swine, and camel medicine can be posted at concerned civil and military farms as well as in such zones and districts where these animals bear economic importance.

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New Thoughts in Home Science

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Profound changes in today's societies are an integral part of the development in the field of Home Science. This atmosphere of change has produced impressive alterations in some of the traditional patterns of education in Home Science.

All the progress that has been made in Home Science in India occurred in less than half a century. The first Home Science ocourses in any institutions of higher learning in India date back to the founding of the Lady Irwin College in 1933. Progress in home science from its inception has been typified by adherence to the concept that the suject has a unique function to perform on the improvement of home and family life at all levels.

Evidence is accumulating which proves that there is a new and creative period in home science thought. Home Science is undergoing scrutiny especially now that the land-grant agriculture universities have been established in many of the states in India and include a College of Home Science. Genuine new dimensions appear to be emerging along with stimulating and challenging programmes that are dedicated to the objectives of teaching, extension and research. Just as creative thought has resulted in breakthrough in the field of study in Home Science in the Government Home Science Colleges in earlier times, so will there be breakthroughs in expanding knowledge of the subject in this decade.

Over the past thirty-five years the profession of home science has developed from one that was limited to only a

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few courses for the house-wife to a field of knowledge that has expanded to include all aspects of food, clothing, shelter, and personal relationships within a family. The time is here when the expanding frontiers of home science knowledge provide opportunities for scholars in the field to extend the boundaries of knowledge so that a deeper understanding of the subject and its contributions can be attained in the education of young people.

Home Science shares the dilemma that faces all education today. The problem is aptly described by Margaret Mead : "We must educate people today in what nobody knew yesterday and prepare people in our schools for what no one knows yet but some people may know tomorrow".

Today the total world is our realm of activity. It becomes important for home scientists to recognise the many and varied ways in which people react to each other and to their physical and psychological environment. Regardless of whether they live in Africa, New York City or rural Punjab, home science subject-matter opens the door to creative approaches to better understanding and the solution of family problems.

In curriculum development, this means an appropriate background in the basic disciplines, the humanities, social sciences, and natural and biological sciences—that will enable the student to comprehend the overall home science philosophy and to develop competence in one or more aspects of professional endeavour. Home Science is an applied discipline which is comprehensive in nature and must continually work to relate meaningfully to the basic disciplines from which it derives substances.

In research, home science is challenged to develop a sound body of information in each of its disciplines and to approach home and family problems from an interdisciplinary point of view.

Research provides a strong impetus to superior teaching, and creative teaching at any level depends on the availability of a fundamental body of knowledge.

Teaching of theory and ideas alone is not enough

for creative education in home science. When the field of home science first emerged in India, no research had ever been done in this field, but the leaders in the profession soon decided that research in the subject-matter of home science was necessary to insure a sound source of information. Teaching of subject-matter that has substance based on research is the teaching that has relevance to both the present and to the future.

Home Science subject-matter that is based on research findings dealing with family problems will provide fundamental principles that have application to a variety of situations, and will have value long after the research or teaching situation is over. The principles based on research will have value for longer than the life of any student or teacher. The principles established by research can also be applied to changing conditions for no single condition is ever static. Therefore, research which provides principles, permits a profession to advance and adjust to dynamic and changing conditions. Since research provides depth in subject-matter, the profession of home science adjusts to everchanging conditions and never becomes static. Furthermore the results of research add to the scientific body of knowledge that forms the foundation of home science subject-matter. This original literature provides the body of knowledge that is drawn upon in the preparation of textbooks, the essential tools for the educational process and then extends the boundaries of knowledge to the villagers through lectures, demonstration and various other forms of communication media.

The aura of provincialism with its strong adherence to rigid, inflexible curriculums and external examinations in home science with too little relationship to the needs of the modern Indian Society is on its way out. A surge of vitality is reflected in the sophisticated approach. Old courses are being revitalized and new courses in tune with the times, are being developed, based on research findings and textbooks whose content stresses greater depth with the intellectual approach. The focus now is on the teaching of concepts and principles applied to home and family life as it exists today rather than on the memorization of facts which were accumulated yesterday.

A Model Course Curriculum for Agricultural Universities

EDITOR

Dr. S. Radhakrishnan (1948-49) pointed out to the Government of India that agricultural education in the country needed immediate reforms which should be considered a matter of national emergency. He pointed out that 70 per cent of the population in India lived in rural areas where agriculture was the primary means of livelihood and that agriculture also contributed 50 per cent of the total national income of the country. In spite of rural biased life of the country there was a deficit in the food production. While highlighting the severity of deficit, he also pointed out that 40 per cent of the population was poorly fed and 20 per cent of the people were very badly nourished. This picture of dismay was considered a sufficient reason for the Government to take up this matter seriously.

Evidently, the urgency of the situation was not realized by the Government of India immediately and it was only in 1955 that a Joint Indo-American Team headed by K. R. Damle was asked to go deep into the matter and make definite recommendations for improving agricultural education and research in the country. The recommendations of this Team were accepted in principle. Apparently, the existing set up in the Central and the State Governments was such that all the recommendations could not be implemented. Thus, the actual task of suggesting a new machinery for the required reforms in agricultural education fell upon the Second Indo-American Team under the Chairmanship of Dr. M. S. Randhawa in the year 1960. It was recommended by this Team that an Agricultural University should be set up in each State on the pattern of the Land Grant Colleges in U.S.A. The first Agricultural University was established

at Pantnagar (U.P.) in 1960 which was soon followed by the Punjab Agricultural University at Ludhiana in 1962, and others in subsequent years.

The universities were started with the faculties of Agriculture and Animal Husbandry, Veterinary and Animal Science, Agricultural Engineering and Technology, and Home Science. For all these faculties certain common courses in humanities and basic sciences were also included. Since the primary aim of the agricultural universities is to prepare graduates for serving the farming community, inter-faculty and inter-disciplinary cooperation was considered very important.

Although various American advisors and the Indian staff who had their advanced training in various Universities in U.S.A., prepared the curricula for their respective Universities, yet it was considered desirable to have, more or less, a uniform programme of teaching in all the Agricultural Universities. Therefore, a Committee of the Deans of the then existing Agricultural Colleges was formed in May 1964 by the Indian Council of Agricultural Research. A draft proposal outlining the curricula and the relative weightage to be given to various subjects was drawn up for consideration in the Second Workshop on Agricultural Universities held at Ludhiana from 16th to 19th February, 1965. As a result, of the deliberations in the Workshop, the Committee of the Deans suggested certain modifications and finally made recommendations at the national level. Naturally, all the recommendations were not accepted by the Agricultural Universities in toto and changes were made here and there. It was recommended that Trimester System of Education should be started and grading should be based on the point system, the weightage being as under :

Grade	*Significance*	*Points per credit hour*
A	Excellent	4
B	Good	3
C	Fair	2
D	Pass but not satisfactory	1
F	Fail	0
I	Incomplete	—

The scholastic standing of a student should be based on

his overall grade point average and it was considered that an average of grade C (2.00 out of 4.00) for the undergraduates and that of grade B (3.00 out of 4.00) for the post-graduates should be the minimum.

In each of the courses in a given trimester there should be a mid-term examination, one or two hourly examinations and a number of quizzes, in addition to the final examination. Since most of the examinations were to be conducted in the normal class periods, quite a number would naturally be of the objective type.

The marking of the individual tests in a course should be on percentage basis and the final percentage calculated by aggregating the marks on which would be based the appropriate grade, A, B, C, D as the case may be.

Thus the academic aims of the Agricultural Universities were as follows :

(i) To prepare a student for proper understanding of his physical and social environment through courses in natural and physical sciences, social sciences and humanities.

(ii) To prepare students for a particular vocation or profession through training in technical and related subjects.

(iii) To have flexible curricula, well-organised courses, inter-faculty and inter-disciplinary coordination, sound teaching/methods and systematic curricula.

(iv) To have in addition to the degree courses, a number of short courses for the inservice staff and the farmers as well as refresher courses.

The aims and aspirations of the students trained under various faculties and the selection of various subject-matters for imparting the appropriate trainings are given faculty-wise. Most of these are adopted from the deliberations in the Second Workshop of Agricultural Universities and the Committee of Deans of various Agricultural Colleges. However, at places, some changes have been made.

I. Faculty of Agriculture and Animal Husbandry : The agricultural graduates trained should be able to understand

and solve various problems of the farmer and hence they should have sufficient knowledge in the following :

(a) Scientific methods of agriculture, including crop husbandry and production of foods of animal origin.
(b) A clear understanding of the agricultural inputs and the principles of production economics.
(c) Some knowledge of the agro-industries important for the rural development.
(d) A field of specialization taken as an elective, in which a student could take up advanced studies, if he so desired. However, it should not be at the cost of the basic knowledge of the science of agriculture.

Normally, a student of agriculture, who joins the College after passing Higher Secondary School examination should spend 4 years and earn 200 credit hours before he should be considered eligible for the degree of B.Sc. (Agri.). The courses suggested are :

Subjects	*Credit hours*
Humanities : English, basic economics, selected Indian and foreign languages, sociology, geography related to plant and animal life	20
Basic Sciences : Physics, chemistry, biochemistry, botany, zoology, geology, microbiology, genetics	40
Applied agricultural sciences : Soil science, agronomy, farm management, horticulture, plant breeding, agricultural economics, entomology, plant pathology, animal science, rural sociology, extension education, agricultural engineering	120
Electives : Any one subject to be selected out of soil science, agronomy, plant breeding and genetics, horticulture, agricultural economics, animal science, biochemistry, entomology, plant pathology, agricultural extension, agricultural engineering	20

Although a student should be expected to study at least

20 credit hours of the electives, yet it should be possible for him to select some courses from the closely related fields, such as plant physiology for a plant pathology student, agricultural zoology for an entomology student, microbiology for a biochemistry student, etc. Therefore, courses totalling 30 credit hours should be listed in the respective departments.

Post-graduate degrees courses :

M.Sc. and Ph.D. programmes should be offered in subjects normally taught as electives. As and when the post-graduate programme could be further expanded those should be broad based and include other specializations in such subjects as food technology, physiology, agricultural engineering, wool technology and textiles and other agro-industries. While offering the post-graduate courses it is most important to lay emphasis on the principles rather than designing a large number of service courses. Some of these courses are listed subjectwise.

Agronomy : Farm layout and records; principles of crop production; fodder and forage production; seed production and testing; agriculture in hilly areas; dry farming concepts of crop science; tilth and tillage; manures and fertilizers in relation to plant growth; weeds and their control; agro-meteorology; cereal crops; fibre and oilseed crops; legumes and pulses; forage crop preservation; agronomic aspects of soil conservation; water and its relation to plant growth; crop geography and ecology; commercial crops, pasture and grassland management; farm cropping systems; principles and practices of irrigation; advances in agronomy.

Animal husbandry : Principles of poultry production; principles of dairy cattle production; principles of swine production; principles of sheep and goat production; live-stock buildings; dairy industry; animal breeding; population genetics applied to animal breeding; breeding systems; selection methods; physiology of reproduction; artificial insemination; animal nutrition; feed stuff analysis; rumen nutrition; dairy cattle nutrition; poultry nutrition; poultry feeding; milk composition and quality control; marketing of milk; general services in relation to dairy plant; dairy plant management; milk products.

Botany and plant pathology : Plant anatomy; principles of plant physiology; diseases of vegetable and fruit crops; diseases of cereals, pulse crops, oilseeds and fodder crops principles of plant pathology; principles of plant protection and disease control; cellular physiology and water relation of plants; photosynthesis and respiration; nutrition and plant metabolism; plant growth and development; plant regulators; thallophytes; embryophytes; embryology and cytology; plant ecology; plant pathology; economic botany; physiogenic diseases; physiology of fungi; systematic mycology; fungal diseases of plants; bacterial plant diseases; plant viruses and viral diseases; plant diseases caused by nematodes; advanced principles of plant disease control; advanced nutrition and metabolism; stress physiology; physiology of flowering; plant viruses: physiology of parasitism; plant bacteriology; ecology of plant disease pathogens

Chemistry & Biochemistry : Organic chemistry; general biochemistry; plant biochemistry; biochemistry of animal functions; principles of animal nutrition; biochemistry—laboratory; physical chemistry; general physical chemistry; chemical thermodynamics; analytical chemistry; advanced organic chemistry; chemistry of natural products; chemistry of pesticides and weedicides; advanced topics in chemistry of pesticides; analysis and preparation of organic compounds; biochemistry of major organic constituents of the body; cell and enzyme biochemistry; intermediary metabolism; advanced physical biochemistry; biological preparations and study of important metabolic reactions; experiments in animal biochemistry; advanced plant biochemistry; advanced ruminant nutrition; vitamins and hormones; mineral nutrition; nutrition of man and monogastric animals; food chemistry; advanced topics in physical chemistry; physical organic chemistry; tracers in biochemistry and nutrition; advanced topics in nutrition; special topics in biochemistry; advanced course in enzymology; proteins and nucleic acids.

Economics and sociology : Fundamentals of economic analysis; income and employment theory; agricultural economics theory; farm planning; introduction to production economics; agricultural marketing; livestock marketing; agricultural finance; introductory rural sociology; rural community organisation; fundamentals of economic analysis; production economics; land and agricultural economics;

marketing of farm products; agricultural price analysis; poultry marketing; agricultural cooperatives; farm business analysis; farm management economics; money and banking; monetary analysis; public finance; social change; advanced rural sociology; diffusion and adoption of agricultural technology; history of sociological tradition; contemporary social theories; rural social systems; techniques of rural analysis; research methodology in social sciences; human ecology and dynamics of population; rural leadership; advanced economic theory; advanced income and employment theory; history of economic thought; national income and social accounting; strategy of economic development; introduction to econometrics; advanced agricultural economics; linear programming and economic analysis; advanced farm organisation and management.

Extension Education : Extension teaching process; extension teaching aids; audio-visual aids; programme planning; principles of communication; communication in extension; agricultural journalism; community development and role of voluntary organisation; extension administration and extension supervision; role and job of the extension worker; extension evaluation; extension research; programme planning; social and educational psychology; extension administration and supervision; developing professional competency of subject-matter specialists; rural youth programmes; extension teaching methods; animal husbandry programmes and policies for rural development; comparative study of agricultural extension programme in selected centres of the world; implications of the principles of educational psychology and sociology in extension work: technique of organising and administering rural youth work; organising and conducting group discussions.

Genetics : Cytology and cytogenetics; plant and animal genetics; principles of genetics; cytogenetics; microbial genetics; population genetics; genetics of population structure; cytological techniques; advanced genetics; advanced cytogenetics; molecular genetics; evolutionary genetics; advanced population genetics; mutagenesis.

Plant Breeding : Principles of plant breeding; breeding of principal field crops; plant breeding practices; recent techniques in plant breeding; plant breeding trials; ad-

vanced field breeding; biometrical approach to plant breeding; cereal breeding for quality control.

Horticulture : Fundamentals of horticulture; fundamentals of fruit production; orchard soil management and irrigation; nutrition of horticultural plants; growth regulators in horticulture; advanced fruit growing; improvement of horticultural crops; elements of vegetable culture; principles of vegetable growing; winter vegetables; summer vegetables; vegetable breeding; vegetable seed production, testing and certification; citriculture; viticulture; growth and development of vegetable crops; advanced vegetable breeding; post-harvest physiology and handling of vegetables; floriculture; principles of landscape gardening; landscaping in relation to architecture.

Mathematics and Statistics : Abstract algebra; linear algebra and theory of matrices; statistical methods for research workers; experimental design for research workers; design of surveys; biological statistics for research workers; economic statistics; general statistics; numerical analysis; functions of real variables; functions of complex variables; probability theory; theory of mathematical statistics; design and analysis of experiments; sampling techniques and design of surveys; sampling inspection and statistical quality control; biological stastistics; time series analysis; probability and distribution theory; theory of statistical inference; general theory of linear hypotheses; multivariate analysis; special topics.

Microbiology : Microbes and agriculture; general microbiology; bacterial physiology and cytology; industrial microbiology; food microbiology; microbiology of milk and milk products; microbial metabolism; microbial biochemistry—laboratory; bacterial genetics; general virology; biology and physiology of yeast; antibiotics; selected topics in bacterial metabolism and biochemical genetics; biosynthesis; advanced bacterial physiology; biochemistry; cytology of bacteria; introduction to molecular biology.

Soil Science : Soil fertility; soil physics; soil survey and classification; soil testing; soil properties in conservation planning; elementary geology; soil microbiology; soil genesis; soil and irrigation water—analysis; soil erosion fundamentals

and control; soil chemistry; fertilizer technology; clay minerology; chemistry of soil organic matter; advanced soil fertility; advanced soil physics; soil survey and classificaton; radio isotopes in soils research; advanced soil chemistry.

Zoology and Entomology : Invertebrate zoology; vertebrate zoology; principles of insect systematics; principles of plant protection; fish biology and management; histology and microtechniques; animal cytology; palaentology and evolution; comparative animal physiology; principles of animal ecology; principles of biological control; insect toxicology; comparative insect morphology; insect ecology; comparative insect anatomy; insect physiology; insect embryology; lepidopterous tissue borers of crops; social behaviour in insects; plant protection equipment; storage entomology; fish ecology; comparative animal embryology; parasities and parasitism; vectors of plant diseases; insect fauna of the State zoogeography; soil zoology; ichthyology; ornithology; mammology; mammalian physiology; nematology; apiculture; general acarology; principles of insect taxonomy; identification of immature stages of insects.

Food Science and Technology : Introduction to general food technology; principles of food processing; methods of food processing; quality of processed foods; food mechanics; food microbiology; enzyme technology; food industry sanitation; quality assessment of foods; meat techonology; poultry products technology; cereal technology; milk composition and quality control; market milk; dairy plant management; milk products—I, II, III; fermented milk products; dairy occurrences; principles of fruit and vegetable preservation; fruit and vegetable juices; canning, freezing and dehydration of fruit and vegetables; plant management (fruit and vegetable products; dairy products; cereal products, etc.); wine making.

II. Faculty of Veterinary and Animal Science : The graduates in veterinary science and animal science should have sufficient training and background for research in these subjects. They should also have the ability to practise clinical medicine and animal husbandry and be able to take up practical farming in all the branches of animal husbandry.

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(a) scientific knowledge of the prevention and
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(b) knowledge of the scientific principles of l
breeding, feeding and management;
(c) scientific tests for the inspection of meat, e
and milk products and their proper stor
preservation.

In order to acquaint the students with these proble
should be taught courses in the following subjects
undergraduate and post-graduate levels :

Undergraduate courses	*Credi*
Humanities : English, sociology; economics; languages	
Basic sciences : General and organic chemistry; biochemistry, general biology, general physiology, microbiology, genetics, mathematics, physics	
Applied Veterinary Sciences : Anatomy, animal physiology, pharmacology and Materia and Medica, animal pathology, bacteriology, parasitology, surgery, gynaecology and obstetrics, veterinary medicine, veterinary hygiene, public health and jurisprudence, meat inspection, clinical practice ..	1
Animal Science Courses : Animal nutrition, animal breeding, management, feeds and fodder production, dairy science, livestock production and marketing, poultry production, swine production, sheep and wool, fisheries, extension methods	
Total ..	2:

Post-Graduate Courses :

Veterinary Bacteriology and Hygiene : Patho
bacteriology; antiseptics and disinfectants; san

and control; soil chemistry; fertilizer technology; clay minerology; chemistry of soil organic matter; advanced soil fertility; advanced soil physics; soil survey and classificaton; radio isotopes in soils research; advanced soil chemistry.

Zoology and Entomology : Invertebrate zoology; vertebrate zoology; principles of insect systematics; principles of plant protection; fish biology and management; histology and microtechniques; animal cytology; palaentology and evolution; comparative animal physiology; principles of animal ecology; principles of biological control; insect toxicology; comparative insect morphology; insect ecology; comparative insect anatomy; insect physiology; insect embryology; lepidopterous tissue borers of crops; social behaviour in insects; plant protection equipment; storage entomology; fish ecology; comparative animal embryology; parasities and parasitism; vectors of plant diseases; insect fauna of the State zoogeography; soil zoology; ichthyolo. gy; ornithology; mammology; mammalian physiology; nematology; apiculture; general acarology; principles of insect taxonomy; identification of immature stages of insects.

Food Science and Technology : Introduction to general food technology; principles of food processing; methods of food processing; quality of processed foods; food mechanics; food microbiology; enzyme technology; food industry sanitation; quality assessment of foods; meat techonology; poultry products technology; cereal technology; milk composition and quality control; market milk; dairy plant management; milk products—I, II, III; fermented milk products; dairy occurrences; principles of fruit and vegetable preservation; fruit and vegetable juices; canning, freezing and dehydration of fruit and vegetables; plant management (fruit and vegetable products; dairy products; cereal products, etc.); wine making.

II. Faculty of Veterinary and Animal Science : The graduates in veterinary science and animal science should have sufficient training and background for research in these subjects. They should also have the ability to practise clinical medicine and animal husbandry and be able to take up practical farming in all the branches of animal husbandry.

It should also be kept in mind that the veterinary graduates would be employed in the military corps, pharmaceutical firms and municipal committees. They should thus have :

(a) scientific knowledge of the prevention and cure of various animal diseases;
(b) knowledge of the scientific principles of livestock breeding, feeding and management;
(c) scientific tests for the inspection of meat, egg, milk and milk products and their proper storage and preservation.

In order to acquaint the students with these problems they should be taught courses in the following subjects at the undergraduate and post-graduate levels :

Undergraduate courses	*Credit hours*
Humanities : English, sociology; economics; languages	20
Basic sciences : General and organic chemistry; biochemistry, general biology, general physiology, microbiology, genetics, mathematics, physics	40
Applied Veterinary Sciences : Anatomy, animal physiology, pharmacology and Materia and Medica, animal pathology, bacteriology, parasitology, surgery, gynaecology and obstetrics, veterinary medicine, veterinary hygiene, public health and jurisprudence, meat inspection, clinical practice ..	150
Animal Science Courses : Animal nutrition, animal breeding, management, feeds and fodder production, dairy science, livestock production and marketing, poultry production, swine production, sheep and wool, fisheries, extension methods	40
Total ..	250

Post-Graduate Courses :

Veterinary Bacteriology and Hygiene : Pathogenic bacteriology; antiseptics and disinfectants; sanitary

bacteriology; veterinary mycology; general virology; systematic animal virology; techniques in virology; immunology and seriology; environmental hygiene and sanitation; public health aspects of milk and meat products; epidemiology and zoonoses; advanced pathogenic bacteriology; advanced virology; advanced immunology and seriology.

Veterinary Gynaecology and Obstetrics : General obstetrics and gynaecology; abnormal pregnancy; normal parturition; abnormal parturition; injuries and diseases of the dam in relation to parturition; reproduction in domestic animals; artificial insemination; infertility in female animals; advanced studies on infertility in male animals; advanced obstetrics.

Veterinary Medicine : Large animal medicine; small animal medicine; infectious diseases of large animals; animal diseases and poisonous plants; poultry diseases; advanced diagnosis and therapeutics of animal diseases, advanced studies in veterinary medicine; advanced poultry diseases.

Veterinary Parasitology : Helminthology (Trematoda); helminthology (Cestoda); nematology; parasitological techniques; veterinary entomology; veterinary protozoology; clinical parasitology; control of parasites.

Veterinary Pathology : General pathology; techniques in pathology; animal oncology; systematic and special pathology; pathology of sheep and goat diseases; pathology of swine diseases; pathology of diseases of laboratory animals; poultry pathology; pathology of nutritional and metabolic disturbances; pathology of toxic plants and extraneous poisons; pathology of bovine diseases; pathology of equine and camel diseases; clinical and post-mortem pathology; experimental and surgical pathology.

Veterinary Physiology and Pharmacology : Myophysiology and neurophysiology, cardiovascular and respiratory system; physiology of body fluids; electrolytes and kidneys'; physiology of growth; physiology of lactation; reproductive physiology; avian physiology; physiology of digestive system; clinical physiological chemistry; pharmacological principles and methods; advanced pharmacology; pharmacology of

indigenous drugs; advanced rumenphysiology; climatic physiology; endocrinology; enzymology and physiology of vitamins; advanced pharmacology and chemotherapy; advanced toxicology.

Veterinary Surgery : General, surgery; radiology; anaesthesiology; bone and joint surgery; regional surgery; special surgery; experimental surgery.

Animal Breeding : Animal genetics and breeding; cytology and cytogenetics; general genetics; statistical methods for research workers; dairy cattle breeding; sheep and goat breeding; swine breeding; poultry breeding; population genetics applied to the breeding; animal breeding systems and selection methods; advanced poultry breeding.

Animal Nutrition : Principles of animal nutrition applied nutrition; feed stuff analysis; dairy cattle nutrition; sheep and goat nutrition; swine nutrition; poultry nutrition; mule and camel nutrition; applied human nutrition; pasture; rumen nutrition; recent topics in animal nutrition; advanced non-ruminant nutrition; advanced animal nutrition; research methodology in animal husbandry.

Animal Production Physiology : Reproductive physiology and artificial insemination; advanced endocrinology; environmental physiology; physiology and biochemistry of semen; physiology of lactation; physiology of avian reproduction and growth; bioenergetics; advanced reproductive physiology; recent advance in environmental and endocrine physiology.

Livestock Production and Management : Dairying; animal production, economics and marketing; dairy cattle production; swine production; sheep and goat production; poultry production; dairy technology; principles of poultry production; principles of swine production; principles of sheep and goat production; livestock and poultry building; dairy industry.

III. Faculty of Agricultural Engineering and Technology : The graduates in agricultural engineering should be acquainted with the principles of engineering as applied to

farm machinery, water and soil management, rural electrification and agro-industries.

It is believed that time has long passed since civil engineering was separated from military engineering and when all aspects of engineering as applied to civil life including industry, roads and buildings, etc., were included in this applied science. Under the modern advancement of technology various branches of engineering have already reached different levels of sophistication, such as thermodynamics, nuclear engineering, aeronautical engineering, marine engineering, etc. etc. It is, therefore, high time that engineering as applied to agriculture should be considered a separate specialization in itself so that the agricultural engineers while making canals, drains, etc., should have sufficient background of agriculture and they be able to appreciate the needs of the farmers. They should, therefore, have the ability to apply engineering principles to Indian agriculture. They should be able to design and direct the maintenance of machinery required for agricultural operations; water management including irrigation and drainage; and soil conservation; farm structures, including houses, barns, storage structures; water supply and sewerage disposal systems; processing plants for farm products and other machinery required for agro-industries; and rural electrification, both for life as well as a source of farm power.

Undergraduate courses	*Credit hours*
Humanities : Sociology, history, English and other languages	90
Basic Sciences : Mathematics; physics, chemistry, zoology, botany, economics, microbiology	20
Agriculture and Animal Husbandry : Agronomy, animal science, soil science, entomology, agricultural extension	25
General Engineering	15
Agricultural Engineering	56
Civil Engineering	22
Electrical Engineering	15
Mechanical Engineering	27
Total ..	270

Post-Graduate Courses :

Agricultural Engineering : Transport phenomena; soil-plant machine dynamics; engineering properties of biological materials; engineering for land development; farm power and machinery management; farm machinery design; handling, size reduction and grading of agricultural products; food engineering plant design; physical operations in food engineering; moisture and temperature control in agricultural processing; environmental control for animal production systems; storage engineering; advanced farm structures; agricultural drainage systems; farm irrigation systems; flow through porous media; ground water engineering; evapotranspiration; hydrology of agricultural lands; mathematical models in drainage research; advanced structures for soil and water management.

Civil Engineering : Open channel flow; concrete dams and reservoir operation; earth dams; irrigation structures; experimental stress analysis; statically indeterminate structures; advanced mechanics of materials.

Electrical Engineering : Signals and systems; instrumentation; servomechanisms; power generation and substation practice; similitude in engineering; electric transmission and distribution; electric power utilization.

Mechanical Engineering : Advanced thermodynamics; advanced Kinematics; refrigeration and air conditioning; vibrations; advanced machine design; advanced fluid machanics; hydraulic machinery.

IV. Faculty of Home Science : The main purpose of home science education is considered to be that the girl students should be so trained as to apply science and economics in houses, and have the training to be good housewives in future, particularly equiped for the rural life. These future housewives should also have the ability to accept responsibility of citizenship, and leadership in rural community. With this training they should be able to handle :

(a) physical needs of the family such as foods, nutrition, housing, sanitation, clothing;
(b) social education, legal rights, developing and

analysing the needs of the individual, the family and the community;

(c) emotional experiences in the course of human development;

(d) the economic, spiritual, cultural and moral needs and the proper management of resources, etc.

(e) child development and child education.

In order to enable them to discharge these responsibilities, the students should have sufficient knowledge in the following courses :

Undergraduate courses	*Credit hours*
Humanities : English, sociology, general psychology, basic economics, applied arts, languages	30

Undergraduate courses	*Credit hours*
Basic Sciences : Physics, mathematics, chemistry, biochemistry, general biology, general physiology, microbiology ..	30
Applied Home Science : Orientation to home science, food and nutrition, textiles and clothing, home management, child development and family relationship, home science extension	66
Agriculture and Animal Husbandry : Agricultural extension, horticulture, animal science ..	10
Open electives	14
Total ..	150

Post-graduate Courses :

Child Development : Statistics and research methods; physical growth; advanced child development; theory of child behaviour; advanced methods and materials; exceptional child; field work; advanced family relations; history of early childhood education; parent and community education; advanced nursery school pra[illegible]; family life education and marriage counselli[illegible] [illegible]ology and adolescence; psychology of maturit[illegible] [illegible]ge

Clothing and Textile : Statistical research methods; textile chemistry; textile study and textile methods; historic textiles and design; advanced draping and pattern-making; advanced tailoring; commercial clothing; textile economics; psychological and sociological aspects of clothing and textiles.

Foods and Nutrition : Statistics and research methods; nutrition experiments on animals; food science; institution management; advanced nutrition; advanced nutritional bio-chemistry; enzymes chemistry.

Home Management : Theory of household management; management problems in home; family economics; home management; house supervision; consumer economics; management of human resources; advanced household equipment; homemaker as an art consumer; housing for family living.

Home Science Education and Extension : Statistics and research methods; field experience and extension; extension method in home science; rural sociology; theory and principles of guidance; preparation and organization of audio-visual materials; economics for rural family; directed teaching; curriculum development and appraisal; community recreation and health; evaluation in home science.

General Guidelines :

1. A credit hour in the Trimester System should normally mean 12 hours of lecturing and 24-36 hours of practicals.

2. Within a curriculum different courses should be so designed as to fit in as segments of the whole and not as independent, clear-cut, unrelated subjects. At the under-graduate level the division of subject-matter into courses should be done very carefully. It is desirable to have fewer courses of greater credit hours rather than a large number of courses with 2-3 credit hours. With this mechanics there will naturally be a better understanding of the subject-matter and yet the courses will complete the whole curriculum, directed towards a definite purpose, be it crop husbandry, or animal husbandry, home science education, veterinary science.

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Clothing and Textile : Statistical research methods; textile chemistry; textile study and textile methods; historic textiles and design; advanced draping and pattern-making; advanced tailoring; commercial clothing; textile economics; psychological and sociological aspects of clothing and textiles.

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Home Science Education and Extension : Statistics and research methods; field experience and extension; extension method in home science; rural sociology; theory and principles of guidance; preparation and organization of audio-visual materials; economics for rural family; directed teaching; curriculum development and appraisal; community recreation and health; evaluation in home science.

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3. Naturally, the elementary or the pre-requisite courses both in the basic sciences and the professional fields, should be offered during the first 3-5 trimesters. The purpose of starting the professional courses at an early stage is to make the students conscious of the philosophy and the needs of the profession. The intermediary courses should be offered up to the 7th trimester, followed by the professional courses. The electives or the courses in specialized fields should be offered in the last two trimesters.

4. Since the students admitted in the first year class would not be familiar with the trimester system of education, greater opportunities of repeating the courses in which they might fail would be desirable. The students should be advised to take fewer credit hours in the beginning.

5. Special care needs to be taken that the students admitted from various walks of life in the highly sophisticated and well-equipped universities, do not tend to become theoretical and idealistic scientists. By the time a student is ready to graduate, he should have sufficient practical knowledge of the various agricultural operations and also have the basic scientific knowledge through which he can explain in accurate but easily understandable scientific terms the various phenomena he is likely to observe in the field. It will, therefore, be desirable to make the students do actual manual work in the field. The nature of the work given to them should be such that they had not covered it in their regular class practicals. They would thus gain practical training in various farm operations, such as, how to drive and handle a tractor, do minor repairs of the farm machinery, to maintain tube-wells, the treatment of seeds and plan materials for the control of various diseases; the handling and maintenance of plant protection machinery, the pruning and proper care of the fruit trees, etc. etc. It is, therefore, essential that before a student is declared eligible for the B.Sc. (Agri.) degree, he should have undergone at least 24 credit hours of practical training.

6. To ensure regular attendance by the students, particularly, the undergraduates, occasional tests through surprize quizzes are the best accepted method in the Trimester system. In India, the students might not easily adjust themselves to the surprise quizzes and they might experience

great mental tension in the beginning. Alternatively, therefore, quizzes can be replaced by regular pre-announced tests in which case certain minimum of attendance (say 85 per cent) should be ensured so that the students do not have a tendency to miss classes and prepare for the examinations scheduled for a particular day.

7. Both for the undergraduate and post-graduate students, it is essential to have a good, considerate and accommodating advisor. The role of the advisor at the undergraduate level is to guide the student in taking the right workload, being regular in studies and maintaining good academic standing, as also helping him in various social, psychological, religious and other personal problems.

Since the post-graduate students are expected to study courses from more than one subject or a department, it is desirable to have an Advisory Committee for each student. The major advisor should be from the Department in which the student is admitted and he is the person who would subsequently guide and supervise his research project. The other members of the Committee should be from the allied and the minor fields. To give examples of these fields, a student who might be doing M.Sc. or Ph.D. in Entomology, might take the related courses in general zoology as the allied field and plant pathology or nematology as the minor field; likewise, a student of agronomy might study soils as an allied subject and agricultural statistics as the minor subject.

8. An M.Sc. student would be expected to study a minimum of 45 credit hours in theory and class practicals, and in addition, to write up a dissertation based on independent research which should subsequently be examined by a scientist of that field from outside the University.

For doctorate programme, a minimum of 30-40 earned credits of course work is essential in addition to the dissertation based on original research which should be examined by a scientist of that field from outside the University.

Both at the Masters' and Ph.D. levels, it would be desirable to evaluate the dissertations separately so as to determine the grade according to the standard of the research carried out.

Before a Ph.D. student is allowed to take up his research, it is desirable to give him a comprehensive examination by the Advisory Committee along with an external examiner so as to determine his overall ability to carry out research of the standard expected of a Ph.D. candidate.

9. Each of the Agricultural Universities should reserve a certain proportion of seats for applicants who are not graduates of that institution. This would serve two purposes, firstly, the exchange of students from one University to the other would help in national and social integration and, secondly, that brilliant students who might wish to specialize in a particular subject in which there might be an outstanding leader in some other University, would have the opportunity to go there and attain the academic excellence that he desired.

Naturally, it would also mean that the various Agricultural Universities should not go out of the way in offering higher degrees in all possible subjects. That is neither possible nor desirable. Even when a post-graduate student has registered in a particular University and has earned the desired credit hours he should also have the opportunity to go out to various Central Research Institutes and Laboratories for completing their research projects under the guidance of competent and outstanding scientists.

10. The B.Sc. (Agri.) and B.Sc. (Home Science) curricula should be suitably oriented as to facilitate a better understanding of the problems of human nutrition. In addition, a series of six special lectures and demonstrations on human nutrition by specialists should be arranged in the final year class so that the students may attain comprehension of the relationship between agriculture and human nutrition.

11. As a national policy some form of physical training either as N.C.C. or compulsory sports or social service is considered essential at the University level. The same policy should be followed in the Agricultural Universities. A separate Directorate of Students' Welfare or Sports should be started in these Universities so that under the guidance of capable staff, visits to various places of educational, cultural and historical importance can be arranged and such other activities as hiking, mountaineering, etc., be encouraged.

In conclusion it may be said that the real test of the Agricultural Universities will be in the quality of the graduates produced and in their ability to be able to solve problems of the rural people. The impact they make will depend upon their ability, integrity and devotion to the task entrusted to them. These qualities are inculcated by good training and are imprinted on their minds by the intellect of their great teachers. It needs to be remembered the great teachers have always succeeded in gathering around them students of outstanding ability and competence which shows in itself the important role of training with a spurpose and training with a mission in life.

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Chapter III

Library—Its Role in Teaching

S. P. Goyal*

A librarian facing educationists to discuss some topics of mutual interest reminds me of a Greek Myth, which is most pertinent to the occasion. The first man, Adam is called Androgene, the Man-Woman, and Woman was created by splitting Androgene into two to help the man and it is said that since then both are seeking each other. The scholar or teacher was his own librarian, but the division of labour and subject specialization has brought into existence the profession of the librarian. My purpose in giving this myth is to emphasize that teaching in a University is a cooperative enterprise; teachers and librarians cannot function smoothly in isolation; the ideal thing is where both teaching and library service can be merged into one to achieve the mission. In some German Universities, lectures are imparted in the library premises in 'Seminar rooms, and books relevant to the lectures are arranged there, which are often consulted to verify the facts, thereby saving the time of teachers, students and library staff, and extending the frontiers of knowledge. This merger of teaching and library service, when applied in developing countries can result in wonderful changes and marvellous progress.

The question arises as to why we teach ? Plato affirms "to give to the body and the soul all the beauty and perfection of which they are capable'. The same idea is reechoed by Kant where he holds,"education should produce the perfect man, sound in character, active in mind and strong in body". To put it in other words one of the essential

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functions of education is to arouse the potential and dormant faculties in the individual and help him in his development and full blossoming, and that process of development of 'self' is a continuous one which spreads over the whole life of the individual. Education, is not over with passing an examination, rather it is the starting point, for man in search of knowledge, is like collecting pebbles on the sea-shores. It starts from the birth of a child and goes till his death. The library is one of the institutions of self education that provides intellectual and literary environment. One can dive deep into the ocean of knowledge for information, inspiration, recreation, research, extension and development of human personality.

Man, we know, is distinguished from the other animals by a number of characteristics, of which the most essential are his ability to use tools, to coordinate his experiences, to communicate them to others to make records. Thus he may send communications across the continents and countries and his organised system of education ensures that the messages are, in fact, passed on from one generation to another. Animals have the foresight to keep larders, but only man keep libraries. University libraries have books and kindred materials on all the subjects in the Universe of knowledge.

Training in the higher branches of learning and research is only a question of learning how to use tools; but if the library tools are not there, how can students learn to use them ? What are the tools ? Essentially they are books and kindred materials like periodicals, maps, charts, micro-films, records, tapes, etc.

Usually in our family budget, we do not have provision for the purchase of books. Text-books are to be purchased, for the students because there is no other alternative. Here the library comes to the aid. University library through its *Book Bank Scheme* can provide students with text-books on a charge of ten per cent of the price of the book. The book is issued to the student for one trimester and he can consider it as his own for that period.

The classification and cataloguing of documents needs to be in a helpful sequence of subjects which by itself is

educative. The arrangement of books on open shelves is helpful in assisting the reader, as the books on related subjects are grouped together e.g. subjects of Biology (570), fossil life or Paleontology (560), and then vegetable life or Botany (580) followed by animal life or Zoology (590), ending with mammals (599): while Technology is (600); then Human anatomy (611) under Medicine (610): this gives a regular growth from fossil plants, through vegetable and animal kingdoms, to living man.

- .The catalogue is there to help, if one knows the author or title or subject of a book. Books on the shelves stimulates interest in preceding and following subjects, as new modes of formation of knowledge like disection, denudation, lamination, loose assemblage and dismembering are putting forth new subjects. The point here is that if the library is used constantly as a workshop, it promotes the dual purpose of teaching self help and acquisition of knowledge at the level of individual interest and ability.

Someone has to mediate between the existing body of knowledge and the user, and it is at this juncture and level that librarian has to organise knowledge and the teacher has to interpret it. The library is a place where properly organised books and effective contacts are made. Readers in themselves do not make the library. The library likewise makes the readers. Dr. Johnson had said, "knowledge is of two kinds, we know a subject ourselves, or we know where we can find information upon it". Teachers have specialized on the first aspect, whereas librarians have on the second. We establish contacts between the right reader and the right book at the right time. This makes it imperative for librarians to know reference tools like encyclopedias, dictionaries, year books, directories, gazetteers, etc., so as to be of assistance to teachers. We share the research work with teachers and scholars, as we have assumed on us the 'search aspect'; thereby saving the time of research scholars, so that they may speedily extend the frontiers of knowledge and contribute to the development of country. We solicit the cooperation of teachers, that when allotting a topic for research, we may be informed beforehand, so that our technical personnel may undertake to find out whether that particular topic has been covered anywhere earlier. With this in mind, we compiled "*Dissertations in Agricultural and*

Animal Sciences, 1948-65". We have other tools such as Dissertation abstracts, indexing, and abstracting journals, which can be of immense help in the choice of a topic for research.

In 1961, Dr. Denjamin S. Bloom had levelled a charge on Indian students, when he mentioned :

> "Perhaps the most important thing I whised to learn was the amount of studying students do during the regular year and the amount and kind of preparation they make for examinations. On the basis of those interviewed, I gained the impression that during the year the typical student spends less than an hour a day on study outside the class-room".

Just an hour a day on studies in University education is no learning. Students in USA devote between 20 and 30 hours per week on studies outside the class-room. Students in U.S.S.R. spend 30 to 35 hours per week. However, in Agricultural Universities, where the dynamic method of the trimester system is in force, we can say that Dr. Bloom's statement is not applicable as students have to read between 21 to 28 hours per week outside the class-rooms. The students have to devote much time to meet their curricular and co-curricular requirements. They cannot depend on a single text-book and have to consult books rather than a book.

We are helping to break the artificial barriers created by the time-table and provide social training. We guide the pupil in choice of books, developing skills and resourcefulness. We encourage the habit of personal investigation and help pupils in having a wider range or interest. Thus the progressive methods of education are put into practice.

We do not just allow periodicals to remain un-opened, encumbering space and burdening the shelves as they keep on accumulating. We attach greatest priority to them because, if books are the life blood of nations, periodicals are their pulse. Journals, year-books and serials keep books up-to-date, as scientific books soon become out-dated. Periodicals are brought to the notice of readers by issuing a weekly publication, "Periodicals received this

week". A simple study indicates that about 16 per cent students use current literature. For popularising the use of periodicals, teachers are requested to refer them to students, as they are important reference tools for scholars. Some important features of our discussion are as follows :

1. The teacher and librarian serve the same end—extension and propagation of field of knowledge. The librarian like a chemist keeps everything in ready stock, while the teacher prescribes.
2. The aim of library service in the College and University are similar : realisation of one's best self and greater social efficiency through education.
3. The teacher lays emphasis on formal education whereas the library, while supporting the programme, takes a broader view in developing the reading habit.
4. At school/college and university levels, the teacher and librarian have to form a team to achieve these ends.
5. The trimester system of teaching places greater responsibility on the student to learn himself the art of enjoyment of books rather than depending on text-books alone.

Dr. Radhakrishanan Commission, and Kothari Education Commission, have emphasized the importance of University libraries in the teaching programme. In fact for scientific research and teaching libraries are as essential as laboratories and for social sciences and humanities they are both a library as well as a laboratory. Because the University library is the centre of all activities, it remains more than a library; it is a laboratory, a 'workshop' for both teachers and students.

Libraries preserve knowledge so that none is lost, organise knowledge so that none is wasted, and make knowledge available so that none is deprived.

Literature and Selective Reading

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PH.D. (OHIO)

The ability of original thinking is limited to a small percentage of human beings and thus it is imperative that the minds of both teacher and taught should be equipped with thoughts of the great men of the past as well as those contemporary thinkers who have sound knowledge to offer.

This mental equipment includes the ideas of thinkers who have been scholars of scientific subjects, discoverers who with keen curiosity have unveiled the secrets of the universe and experimenters who have probed their way into trackless fields in order to present to the world concrete and useful knowledge. Others who have not completed the task of experimenting have suggested fascinating new paths of knowledge over which the teacher is tempted to follow in order to discover new facts for himself or at least to ponder over possibilities suggested by unproved thought.

Full understanding of a subject results after the entire mass of knowledge related to the subject is assimilated. This might mean the acquiring of basic knowledge in the first instance from literature available. Basic knowledge should logically lead to accumulated knowledge terminating in a store of facts that are unquestionably correct.

Thus literature leads to the satisfaction of curiosity and the acquiring of confidence. Facts are the teacher's best equipment, for without sound knowledge teaching is meaningless.

Literature forms the stepping stone to research and

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experimentation. The assimilation of literature leads to a renewal of curiosity and interest. It is the gushing spring that leaves the one who tastes its waters, ever thirsty. It is closely related to life for facts once understood are tested and tried by experience.

Meaningful reading leads a new outlook and a deeper insight into the life of things around us. Thus the seed, the plant or the soil which on the surface appear commonplace take on a new significance when viewed through the telescope of knowledge. They become not just familiar objects but a fascinating challenge to the human mind.

In addition to basic facts and the systematic body of scientific knowledge, it is necessary that the teacher should be aware of conflicting and varying theories and ideas of a given subject so that he inspires the student to pass from knowledge to judgement and an ability to weight and understand conflicting ideas.

The vista of knowledge before the teacher should be far wider than what is set down in the prescribed courses of study. Unless the teacher becomes a pioneer and an adventurer in the field of literature teaching, will be dull and mechanical, limited by the narrow bounds of restricted thought. Equipped with the treasurers of literature, the teacher can impart knowledge in a spirit of inspiring enthusiasm.

The relation between theory and practice is both close and binding. Practical work has for its basis, sound academic knowledge, without which, the teacher is as lost as a traveller who is ignorant of his destination. The farmer who labours year after year on his fields makes less progress and gets a smaller returns than the well taught student who is equipped with a thorough knowledge of the soil and up-to-date methods. Sound theory leads naturally to better practical results. Thus literature which has a bearing on the field of study is not only a need but an absolute necessity.

Literature results in the formation of an open mind that responds to the pressure of one great factor—the pressure of truth. Wise reading equips the mind and results in a sense of judgement so that mind weighs situations in relation to facts. Changing conditions are made more acceptable and

obsolete facts are discarded. Reactions are predicted from the standpoint of knowledge and experience.

Literature is always related either directly or indirectly with the needs of life and as human needs change, they present new problems to be solved. Thus the demand for more food or greater speed looms before the world and the young scientist who will finally solve these problems will be the one whose knowledge is both deep and elastic and whose outlook is versatile and adventurous.

The approach to reading should be practical. It stands to reason that reading should be selective if it is to be of use. The teacher cannot delve haphazardly into the vast store of knowledge available, as both efficiency and speed are required of him. Material that has a direct bearing on the subject must be tackled. Concentration on limited reading is especially required for teachers who are interested in research or who are guiding research. With selection, there must be systematic reading and careful organisation of information.

Reading for purposes of imparting knowledge should be related to the requirements of students at each special stage. Thus reading for undergraduates should necessarily differ from reading undertaken for post-graduates.

The library forms the chief source of material for reading. It is essential that the teacher should be well-informed and acquainted with the latest knowledge available. Modern text-books, journals giving abstracts, and series of advances in a particular area of science and monographs should be fully utilised to keep abreast with up-to-date knowledge.

Apart from libraries, the teacher can gather material by maintaining personal contact with well-informed, outstanding workers in the field.

Seminars and symposiums are instrumental in building up and perfecting the teacher's knowledge.

Without literature and wise reading the teacher shall fail to inspire and enlighten his students.

Selection of Scientific References and their Effective Use

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As with children learning to read, we step with indifference into the world of books. The simple, process of reading has the desired effect of raising the readers standard, of increasing his intelligence and knowledge and of sharpening his finer instincts.

Text-books and standard works need duplication in our libraries, especially in a poor country like ours where students can scarcely afford to buy costly books. Adequate provision for parallel and follow up studies as well as for reference works should be made. The research worker should be provided with first line material as far as possible in that subject. Best books should be available and duplicated rather than many acquired. The books should be acquired for positive use. A book should not simply be good, it should be good for something. It must give service. In short, we should "know books". The right book should be available to the right reader at the right time. This is the essence of book selection.

Each book usually consists of the following parts :

1. Title page
2. Copyright date
3. Preface
4. Introduction
5. Foreword
6. Table of contents

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7. Index, cross references
8. Text, foot-notes
9. Illustrations
10. Appendix

Each part of the book has its own significance and reveals information towards the usefulness of the book on a particular topic. One should look at the title, its table of contents which usually define the scope of the book. It is no use picking out books at random and reading them. Each title should be thoughtfully selected, its contents sifted and then one can proceed with the book if it contains the sort of material one needs. Once the right kind of books have been selected, it is imperative that we should be able to make effective use of them. This involves the study of the books which is the major element in refernece reading. We should be able to "read" our literature in the true sense of the word, be it a particular research paper or a portion of the book. The process of "reading" is the same. However, the purpose may be slightly different as we build upon the text-book knowledge.

Why books are necessary ? During our time, we passed courses with creditable marks. The game was easy enough, once you caught on to the tricks. If anyone had told us then that we did not know much or could not read very well, we would have been shocked. We were sure we would listen to lectures and read the books assigned in such a way that we could answer examination questions neatly. That was proof enough of our ability.

We may be college students—perhaps candidates for a higher degree and yet not realize that what is happening to us is stuffing, not education. There are many college students who know certainly by the time they get their Bachelor's degree, that they spent four years taking courses and finished them by passing examinations. The mastery attained in that process is not of subject matter, but of the teacher's personality. If the student remembers enough of what was told to him in lectures and text-books and if he has a line on the teacher's pet prejudices, he can pass the course easily enough. But he is also passing up an education.

We may be teachers in some college, or University,

but I hope that most of us realize that we are not expert readers. I hope we realize that our students not only do read fairly but also that we cannot do much better. Every profession has a certain amount of humbug about it necessary for impressing the laymen or the clients to be served. The humbug we teachers have to practise is the front we put on knowledge and expertness. It is not entirely humbug, because we usually know a little more and can do a little better than our best students. But we must not let the humbug fool ourselves. If we do not know that we cannot read very much better than the students, we have allowed our professional image to deceive ourselves. Perhaps if we teachers were more honest about our own reading disabilities, less loath to reveal how hard it is for us to read and how often we fumble, we might get the students interested in the game of learning instead of the game of passing. To be informed is to know simply that something is the case. To be enlightened is to know, in addition, what it is all about, why it is the case, what its connections are with other facts and in what respect it is the same and different and so forth.

When we read for information, we acquire facts. When we read to understand, we learn not only facts but their significance. Each kind of reading has its virtue, but it must be used in the right place.

Being well read means too often the quantity and seldom the quality of reading. It was the pessimistic and misanthropic Schopenhaver who weighed against too much reading, because he found that for the most part, men read passively and glut themselves with toxic overdoses of unassimilated information. Bacon and Hobbes made the same point. Hobbes said, "If I read as many books as most men", he meant "misread" I should be as dullwitted as they. Bacon distinguished between "book to be tasted, others to be swallowed, and some few to be chewed and digested". The point that remains the same throughout, rests on the distinction between different kinds of reading appropriate to different kinds of literature.

In the history of education, men have always distinguished between instruction and discovery as sources of knowledge. Instruction occurs when one man teaches another through

speech or writing. We can, however, gain knowledge without being taught. If this were not the case, and every teacher had to be taught what he in turn teaches others, there would be no beginning in the acquisition of knowledge. Hence there must be discovery, the process of learning of something by research, by investigation or by reflection, without being taught.

Discovery may be compared to instruction as learning without a teacher to learning with a teacher. In both cases, the activity of learning goes on. It would be a great mistake to suppose that discovery is active learning and instruction is passive. There is no passive learning, as there is no completely passive reading.

The difference between the two activities of learning is with respect to the materials on which the learner works. When he is being taught or instructed, the learner acts on something communicated to him. He performs operations on discourse written or oral. He learns by acts of reading or listening. Note here the close relation between reading and listening. If we ignore the minor differences between these two ways of receiving communication, we can say that reading and listening are the same art, the art of being taught. When, however, the learner proceeds without the help of any sort of teacher, the operations of learning are performed of nature rather than discourse. The rules of such learning constitute the art of discovery. If we use the word "reading" loosely, we can say that discovery is the art of reading nature, as instruction (being taught) is the art of reading books or to include listening or learning from discourse.

It is important to know how we think when we read a book or listen to a lecture. Perhaps it is even more important for teachers who are engaged in instruction, since the art of teaching must be related to the art of being taught, as the art of writing is related to the art of reading. I doubt whether anyone who does not know how to read well can write well. I similarly doubt whether anyone who does not know the art of being taught is skilled in teaching. The cause of these errors is probably complex. Partly they may be due to the false suppostion that teaching and research are activities, whereas reading and being taught are merely passive. Much more time is spent in training students how

to discover things for themselves than in training them how to learn from others. There is no particular virtue in wasting time to find out for yourself what has already been discovered. One should save one's skill in research for what has not yet been discovered and exercise one's skill in being taught for learning what others already know and therefore can teach.

A tremendous amount of time is wasted in laboratory courses in this way. The usual apology for the excess of laboratory ritual is that it trains the student how to think. True enough, it does, but only in one type of thinking. A roundly educated man, even a research scientist should also be able to think while reading. Each generation of men should not have to learn everything for themselves as if nothing had ever been learned before. In fact, they cannot.

Unless the art of reading is cultivated, the use of books will steadily diminish. How to read a book by M. J. Adler, Published by Simon and Schuster. N. York, 1959 illustrates this point well.

There is no point in our ancestors talking to us (through books) unless we know how to listen. The teacher should be able to help in this process. However, if the teacher answers the question, that does not mean that the student has no further work. If the student is seeking an explanation, he must understand it; otherwise nothing has been explained to him. Books can be read under the guidance and help of teachers. So we must consider the relation between books and teachers—between being taught with and without the aid of teachers. Obviously, it is a matter which concerns us all who are in the profession of teaching.

We can be instructed by listening to a lecture as well as through reading a book. That is what brings us to the consideration of books and teachers, to complete our understanding of reading as learning.

Teaching is the process whereby one man learns from another through communication. Instruction is thus distinguished from discovery which is the process whereby man learns by himself, through observing and thinking about the world and not by receiving communication from other men. These two kinds of learning are intimately and intricately

fused in actual education of any man. Each may help the other. But we can always tell whether we learned something we know from someone else or whether we found it out ourselves.

Considered as a source of knowledge, the teacher completes with or cooperates with books. By "competition" is meant here the way in which many teachers teach their students through lectures what the students could learn by reading the books themselves. By "cooperation" is meant the way in which teacher somehow divides the function of teaching between himself and available books : some things he tells the student, usually what he himself has read, and something he expects the student to learn by reading. If these were the only functions, a teacher performed with respect to the communication of knowledge, it would follow that anything can be learned without the teacher. It might take a little more trouble to read for yourself than to have books digested for yourself. You might have to read more books, if the books were your only teachers.

If what you seek is understanding rather than information, reading will take you farther. Most of us are guilty of the vice of passive reading, of course, but most people are even more likely to be passive in listening to a lecture. A lecture has been well described as the process whereby the notes of the teacher become the notes of the student wihout passing through the mind of either.

Note taking is usually not an active assimiliation of what is to be understood, but an almost automatic record of what was said. The habit of doing it becomes a more pervasive substitute for learning and thinking as one spends more years in educational institutions. It is worse in professional institutions such as medical and graduate schools. Someone said you can tell the difference between graduate and undergraduate students in this way. If you walk into a classroom and say "Good Morning" and the students reply, they are undergraduates, if they write it down, they are graduate students. Most of them take the course for credit, not merit. Since the examination does not measure understanding but information, they probably regard the explanation of the teacher as waste of time. Also, the teacher today is primarily a man of learning rather than a discoverer. He is one who

learned most of what he knows from other teachers, dead or alive. Let us consider the average teacher today as one who has no original communication to make in relation to books, therefore, he must be either a repeater or a disgester. In either case, his students could learn everything he knows by reading the books he has read. The paraphernalia of lectures, assignments and examinations may be a more sure and more efficient way of getting a certain amount of information, and even a little understanding into the heads of the new generation. Even if we train them to read well, we cannot be assured that they shall continue to read in order to learn.

Indexing and Abstracting Services in Agricultural and Allied Sciences

T. C. Jain*
C. D. Handa**
H. D. Sharma***

Introduction : The role of agriculture in human life is basic and fundamental from time immemorial and shall remain the same. The geometrical progress of the population and the limited land resources are already telling upon the present feeding position. The clouds of famine are already overcasting the skies of many countries. The deaths due to the shortage of food supplies is a challenge to the whole of humanity. This challenge is being met by the untiring efforts of thousands of research workers in the field of agriculture. Thus, the importance of agriculture and allied sciences can hardly be exaggerated.

1. *Development of agricultural literature :* The development of agricultural literature, if surveyed, reflects that good farming existed even as early as 7500 B.C. The first printed book was issued from Augsburg (Petrus Crescentius, *Liber ruralium comodorum*). The first English work on agriculture was by John Fitzherbert's *Boke of Husbondrye* (1523), described as presenting the best principles of farming at that time. Although the production of the agricultural literature was always on the increase yet the 18th century witnessed the ending of the empirical period and the beginning of the scientific approach. The first attempt to found a scientific agricultural periodical was John Houghton's *Collection of Letters for the Improvement of Husbandry and*

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Trade (1681-3) F.A. Buttress in his *Agricultural Periodicals of the British Isles*, 1681-1900 (1950) records some 400 items, clearly showing the increasing tempo of agricultural literature production. (1) The advancement in the printing technology has played a key role in the production of agricultural literature. The agricultural literature is advancing so much that even 12,500 periodicals as indexed in *Current agricultural serials* (2) are not able to accommodate its mutlidimensional expansion.

2. *Problems of research scholars :* The enormous literature in the field has posed a problem for the research scholars and they feel baffled amidst these literary surroundings. The technique of literature searching, therefore, is gaining momentum owing to its importance. Lack of knowledge about the already explored fields of the 'Universe of Knowledge' can result in unproductive and duplicate research. Research Scholars are basically faced with the two main problems. Firstly they cannot lay their hands upon the whole material related to the fields of their respective problems since the vastness of the literature stands in their way; and secondly even if they may get the entire literature, the time factor would not allow them to go through all of it. These two problems have been solved by the indexing and abstracting of periodicals.

3. *Indexes and indexing periodicals :* 31 *Indexes :* Each index is a key to the information contained in a publication, its proper use is of paramount importance. It is particularly striking in abstracting and indexing periodicals which have elaborate indexes based on their own special systems. The Oxford and Webster's dictionaries have practically the same definitions for the word 'index' used as a guide to information—viz., "an alphabetical list, usually at the end of a book, of the names, subjects etc., occuring in it with indication of places where they occur". This definition is elementary, and though it may be aplicable to books in general, it is only partially applicable to technical text-books, which index to a greater extent than the other. Still less applicable is it to such an abstracting periodical as *Chemical abstracts* or *Biological abstracts*. The indexes of these periodicals are more than an alphabetical list. A more comprehensive definition is, therefore, required. "Indexing is an art of

assigning one or more terms to an item of 'information' so as to characterize it". The word 'term' is used here in its broadest sense and comprises any form of class, subclass, subject, heading, single word or combinations of words. (3) This definition has the scope of covering all indexes such as subject index, author index, biosystematic index, cross index and key word index, patent index, formulae index, citation index etc.

32 *Indexing periodicals :* The origin of the indexing periodicals can be traced to the work of William Frederick Poole (in 1847, who compiled an index consisting of 154 pages. Instead of searching through the indexes of different periodicals he found it convenient to prepare a single index for his reference of the subjects of his interest in various periodicals. In 1876, at the first meeting of the American Library Association, a group of 50 Librarians agreed to cooperate voluntarily to improve the index. In 1882 a large volume indexing 232 periodicals 1802-81 was published. People's index was superseded in 1900 by the *Readers' guide to periodical literature.* (4) Since then many learned societies and organizations are engaged in compiling the Indexing periodicals. In the field of agricultural and allied sciences, the *Bibliography of agriculture* (USDA) and *Biological and agricultural index* (HW Wilson) have their own place.

321 *Bibliography of agriculture :* The *Bibliography of agriculture* is an index to the literature of agriculture and allied sciences received in the National Agricultural Library (USDA). Publications from all parts of the world are indexed, provided they are in one of the languages approved for publication in the *Bibliography of agriculture* or have summaries, abstracts or translated titles in one of those languages. Literature received after more than one year of its publication is generally not indexed. Unsigned articles and those signed with pseudonyms or initials, editorials, letters to the editor, and columns appearing regularly are omitted. The Bibliography has a classified arrangement of references under the subjects. Agricultural Economics and Rural Sociology, Agricultutal Products, Animal Industry, Engineering, Entomology, Food and Human Nutrition, Forestry, Plant Science, Soils and Fertilisers, Miscellaneous. Every issue is preceded by the pages of contents in which the

further sub-divisions of the subjects cited above and their place of location is indexed. It also contains a personal index and organizational index.

322 *Biological and agricultural index :* The *Biological and agricultural index* is a cumulative alphabetical subject index to the periodicals in the fields of biology, agriculture and related sciences. It is published by HW Wilson, New York. Formerly it was published as Agricultural Index. Monthly issues are superseded by quarterly and yearly cumulations. It is an alphabetical subject index to bulletins, books publications of USDA, experimental stations, extension services, agricultural societies etc.

323 *Current contents :* The *Current contents* reports weekly the tables of contents, in original format, of more than 800 research journals—many in advance of publication date. It is a comprehensive service designed to aid the scientist who must keep pace with new developments in his own and peripheral fields. Reporting over 150,000 articles per year, it is an effective answer to the reading selection problem, while it fills the ever-increasing need to disseminate important information quickly, efficiently and economically. An author's address is listed for each article and original article Tear Sheet service is available.

4. *Abstracts and abstracting periodicals :* The scope of the indexing periodicals is limited by its own nature. A limitation on the usefulness of indexing periodicals is firstly that the few libraries subscribe to all the periodicals indexed in a particular indexing periodical; secondly the scope of the particular indexed reference cannot be evaluated. The role of abstracting periodicals, therefore, is more comprehensive.

41 *Abstracts :* An abstract is a complete citation and condensation or summary of essential facts, theories and opinions presented in an article or book. It is frequently published at the beginning of an article or is an abstracting journal. Unlike indexes, the value of abstracts depends upon the qualifications of the abstractors. The abstract may be prepared by the author himself or by the editor of the periodical or by some other specialised person in that particular field. The author while preparing the abstract should

keep in mind the recommendations of the UNESCO, International Council of Scientific Union Abstracting Board. The summary of recommendations can be found in the *Style manual for biological journals* (5).

42. *Abstracting periodicals :* Sir David Chadwick, following definitions and characteristics of abstract journals and abstracting agencies at the Royal Society Conference said "The characteristics of an abstract journal, whatever its title are assumed to be as follows : it is compiled and issued regularly, is devoted in whole or large part to abstracts of scientific papers, is under scientific editorship, i.e. a scientist trained in its subject and known by name (or a committee of scientists or a scientific society), responsible for the accuracy of the abstracts issued. In other words, it claims authority, An abstracting service or agency denotes the organization responsible for the compilation and issue of such abstracts whatever other duties it may discharge."

The ideal abstracting periodical is non-critical, covers its field completely, maintains a high quality in its abstracts, is prompt in its publication of the summaries and prints good annual and collective indexes. The cumulative index covering several years is a great time saver for the busy researcher.

The first abstracting periodical, the *Pharmaceutisches centralblatt* (later the *Chemisches zentralblatt*), started in 1830, is still being published. This was followed by the *Quarterly journal of Chemical Society* now the *British chemical abstracts*. Since then the number of abstracting periodicals have always been on the increase. The following are the important abstracting periodicals in the field of agriculture and allied sciences :

Biological abstracts (including BASIC, Bioresearch index)	Published by Bio-science Information Service.
Chemical abstracts ..	Published by American Chemical Society.
Dissertation abstracts ..	Published by University Microfilms, Michigan.
Review of applied entomology (series A & B)	Published by Commonwealth Agricultural Bureaux.
Animal breeding abstracts ..	-do-

Dairy science abstracts	..	Published by CAB
Field crop abstracts	..	-do-
Forestry abstracts	..	-do-
Helminthological abstracts	..	-do-
Herbage abstracts	..	-do-
Nutrition abstracts and reviews		-do-
Plant breeding abstracts	..	-do-
Review of applied mycology	..	-do-
Review of medical and veterinary mycology	..	-do-
Soil and fertilizers	..	-do-
Veterinary bulletin	..	-do-
Weed abstracts	..	-do-
World agricultural economics and rural sociology abstracts		-do-

Each abstracting periodical is accompanied by the various types of indexes which are directly in accordance with the policies of the particular periodical.

421 *Biological abstracts :* "It is a comprehensive abstracting and indexing journal of world's literature in theoretical and applied biology. In its departments dealing with theoretical and applied bacteriology and Botany, this journal represents a continuation of *Abstracts of bacteriology and Botanical abstracts.* Also it includes material formerly abstracted in the Experiment station record". (7) Its annual coverage from 1967 will be 125,000 reports of the world's bioscience research in abstracts form. In addition to it the coverage of Bioresearch index will increase to 75,000 reports which is also an important service of the Biological abstracts.

Biological abstracts has its own several special features. In order to use it profitably, the users should have complete knowledge of the following special features and indexes of this periodical :

(i) Table of contents—an alphabetical list of 500 subject fields under which the whole literature is abstracted.
(ii) A list of new books and periodicals received is recorded in front of each issue of Biological abstracts and is subsequently reviewed and reported

in the abstract portion.

(iii) It has its own subject classification outline which consists of 450 topics and sub-topics. The abstracts are classified in accordance with this outline. This outline of the classification is given in the first issue of every volume.

(iv) The Author index is a computor index and all the names including the corporate authors are arranged strictly in an alphabetical order.

(v) The biosystematic index provides bioscientists with quick access to all research studies grouped according to taxonomic position of the organisms under investigation.

(iv) The cross index given at the back of each issue of the Biological abstracts is a rapid, selective device for both current and retrospective searches. Numbers of all abstracts pertaining to each of 500 subject fields are listed under that subject heading. The cross is arranged to correspond to the order of subject, listing in Biological abstracts, with vertical columns numbered 0-9, under which abstract numbers are grouped according to their terminal digits.

(vii) Biological abstract subjects in context (BASIC) is a computor key word index to each issue of the Biological abstracts. Each key term is listed alphabetically, surrounded by parts of the title which precede or follow the key wovel.

(viii) Bioresearch index, a montly publications was introduced in 1965 as Bioresearch titles. This contains 75,00 reports in addition to and different from those published in Biological abstracts in 1967. A bibliographic citation is given for each paper, with subject, cross, biosystematic and author indexes included in each monthly issue.

422 *Chemical abstracts :* Chemical Abstracts is one of the best known of the scientific abstracts. It was started 1907 by the American Chemical Society to replace the *Review of American chemical research* (1895-1906). The complete coverage of chemistry and chemical engineering has long been attempted as a significantly worthy goal. The approach of completeness has been so close that a researcher can use Chemical abstracts with reasonable confidence that

he will not miss important contributions if his search is careful and thorough. The publication of adequate abstracts and of full, well-constructed indexes is a factor in completeness, as well as is the reporting of all suitable, published papers and patents. (8) *Chemical abstracts* has a large staff of abstracts well over 2,000. These chemists constitute a representative group because all kinds of chemists are needed in approximate proportion to the research activities in the various branches of field of chemistry. Chemical Abstracts is thoroughly and carefully indexed by the following indexes :

Author index
Subject index
Numerical patent index
Formulae index
Patent concordance

Numerical patent index, formulae index, and patent concordance are the rare characteristics of this periodical.

423 *Dissertation abstracts :* Abstracts of dissertations and monographs in microfilms are prepared monthly by University Microfilms, Michigan. American Doctoral dissertation which previously appeared as number 13 of the Dissertation abstracts has not taken the shape of an independent periodical.

424 *Abstracting periodicals of Commonwealth Agricultural Bureaux (CAB) :* All the abstracting periodicals published by the Commonwealth Agricultural Bureaux (and as listed earlier in this paper) have a similar pattern among themselves. Each issue of the periodical has a table of contents giving the subject fields covered by it. The author and subject indexes are annually cumulated. *Weed abstracts* has its own special feature in the form of 'species index' cumulated annually. Each one of the CAB periodicals has its specific field and scope.

5. *Conclusion :* With the advancement of production of scientific literature, the indexing and abstracting services for literature-search have become the integral part of scientific and industrial research.

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Chapter IV

Biology—A Life Science

S. S. Bains*
AND
A. S. Atwal**
PH.D. (ADEL.)

Biology is a science concerned with countless living things, their structure, function, evolution, development and relations to their development. This branch of science called a life science is very old in the respect that man began its study many centuries ago in order to solve the fascinating riddle of life. Thus, man probably was a biologist before he was any thing else; yet in another sense biology is a young science, as the major generalisations considered to be the foundations of biology have been made comparatively recently. Although life has intrigued man since the very beginning of recorded history, even today after all our scientific advances much remains to be learnt. Biology which started with the study of zoology and botany has grown much too broad a Science to be investigated by a single man and encompasses several special fields of study. Most biologists of today are specialists in one or two of the biological sciences but not to the exclusion of others.

Early history of biology : Scientific discussion is known to have begun with the Greeks, and the earliest known scientific institution arose about 600 B.C. The works of the greatest member of this School, Hippocrats, often spoken as Father of Medicine have come down to us. Thus the biological sciences were first studied because of their bearing

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on medicine. Aristotle was the first great biologist who devoted himself to the study of natural history. He recorded biological observations very accurately, reasoned out these observations in terms of his philosophy and gave answers to a great many questions that arise to our mind about the structure and function of an animal. Since Aristotle had supplied answers, these were accepted for many centuries as correct without being tested, even though many of the answers were not correct.

In his efforts to differentiate between living and non-living things, he came to differentiate between a vegetable, an animal and a rational soul. According to him, plants were the lowest living form, had qualities of nutrition, growth and power of reproduction while animals also had the power of movement and men had all these qualities but had also power of reason. Aristotle arranged living things in a serial order, a *scala naturae*, a *ladder* of nature which is a subject of great interest and worthy of respect.

Zoology and physiology received more attention than botany by Aristotle. His pupil and successor Theophraties has, however, left two treatises on botany, the one on the History of plants being more interesting. His work include a collection of drug plants and a description of the process of germination.

Anatomy became a recognised discipline at Alexandria during the Ptolemaic reign. The art of botanical drawing developed during first century B.C. which helped a great deal the rural study of nature. The development of Roman empire was accompanied with greatly improved means of communication and thus complexity of life. As a result, the difficulty of identification of plants cropped up. The first efforts for identification of plants came from Plinny and Dioscoridies. This work in biology was followed by Galen's work in human anatomy and physiology.

After Galen, there was no biological activity for many centuries. There was a decline in activity and this age (A.D. 200-1200) came to be known as the Dark Age. The main reason of his decline is considered to be the apathy of ruling class in the Roman empire towards science. The contempt for and neglect of science by the Romans teaches us a lesson

which is of great value even today. If a time should ever come when the importance of theoretical knowledge is neglected, our science will go the way of the Greek. The importance of abstract science studied for its own sake should not be forgotton. For example, transport of our food supplies depend intimately on discoveries made without thought for their practical application.

Thirteenth century revival of learning : The revival of learning came with the rise of the great movement of Islam and translation of Greek works into Arabic. The movement of great religions and artistic revival in the Gothic style also had an effect on biology. The system of thought that arose from study of translated texts is known as scholasticism—characterised by interest in words as opposed to things.

Rebirth of enquiry : The 14th century was the period of travel and expeditions. The naturalistic representations became more successful by the 15th century. Rediscovery of antiquity followed and aroused curiosity as to the material remains of ancient civilizations. The study of masterpieces of the great Italian artists enabled representation of nature more accurately. The greatest representative of Renaissance artists—naturalists was Loenardo de Vinci.

In the 15th century the so-called humanists moved by the spirit of antiquity turned to great scientific works of Greeks; intoxicated by the beauty of classic they developed furious enmity against scholastics. They castigated texts and purified the language by removing words of Arabic origin and substituted Greek and Latin terms. With the development of the craft of printing in the beginning of 16th century, the first adequately illustrated books in biology were produced.

The first great work in anatomy came from Vasalius the real father of modern anatomy, in the form of his *De frabrica corporis humani* which was repeatedly reprinted, abstracted, copied and pirated and its influence can be traced right into the 20th century. At the end of 16th century Harvey brought an end to the vagueness in describing the living process and, in a sense, initiated the modern period of biology.

Historical foundation of modern biology : The advent of 17th century brought great changes in the philosophical outlook of the age. The nature of the physical world began to be revealed by new means of investigations. The introduction of the microscope by Galileo greatly improved the works of nature and helped a great deal in the study of anatomy and embryology. The Bible of nature by Swamerdam is the finest collection of microscopical observations ever produced by one worker. The science of histology was founded by Anatony Van Loewenhoek. The knowledge of the infinitely minute complexity of the structure of living things gave a new and more philosophical trend to biological thought, and the importance of classification was the natural outcome of all this.

Rise of classificatory system : The accumulation of masses of information gave rise to the necessity of classification and systematic biology received the attention of biologists of the 16th century. The great Swedish naturalist Carl Linnaeus (1207-78) who had a passion for classification, not only classified plants and animals but also minerals and diseases. For work on plants and animals, naturalists still refer to Linnaeus. He succeeded in assigning to every known animal and plant a position in his system. According to Linnaeus there were just as many species as were created in the beginning and there was no such things as new species, but his stand point was rejected completely. Since the time of Linnaeus almost every important biological movement has left its mark on the system of classification.

Rise of the comparative method : The comparative method based on similarity and differences was adopted in 17th century when anatomical monographs of various vertebrates appeared; the most remarkable comparative study being that of Grews' on the stomach and gut (1681) based on a study of 35 different species. The biologists in that age were divided into two camps; free thinkers and Christians. Scientific men of our own time still consider teleology to be the enemy of science. The thought of this age was given new directions by Immanuel Kant (1727-1804). It was his view that the two camps were not opposite and irreconciliable. In thought Kant said, "We pass constantly from the mechanist view of parts to the teleological view of the whole and back again."

The principle of the correlation of parts gave guidance to the work of George Cuvir called the Director of Biology (1769-1832). Cuvir gave us the great book "Le Regne Animal" (1817), the most comprehensive biological work since Linnaeus. This book describes a species from almost every genus then recognised and is illustrated by beautiful diagrams. Cuvir's work lit up a zeal for comparative anatomy and paleontology which lasted throughout the 19th century.

Organic evolution : The naturalists who were carried on voyages of explorations in 18th century made wonderful collections of fauna and flora. Darwin's exploration and survey on *Beagle* was a very important event in the history of biology. This was followed by a number of explorations of the sea. The extension of our knowledge of the sea, gave us an idea of the most impressive physico-biological integration between plants and animals. It was during this period that natural barriers delimiting flora and fauna came to be noted. Wallace divided the land surface in six zoogeographical regions. The geological succession, interrelation of species and migration of animals received attention of biologists in the 19th century. Evolution at the end of 19th century was accepted as a general description of history of organic forms. The idea of succession of living things summed up in the words of organic evolution by Darwin profoundly influenced every branch of biological inquiry. Darwin's contribution to biology as a naturalist is no less important than his theory of organic evolution.

Development of main themes of biology : During the early part of the 19th century the importance of the cell structure of organisms gradually became obvious. According to Wilson E. B. (1925), the development of the cell theory was a turning point in biology, a scource of fruitful researches and one of the commanding land marks of the 19th century. He suggested that the key to every problems must be sought in the cell because every living organism at sometime has been a cell. Cell biology led to progress in physiology and pathology and to the development of the new science of cytology. As the fundamental importance of cell division in reproduction of both plants and animals was demonstrated, it helped to solve, the riddle of origin of individual life and to detailed studies now going on the heredity and genetics.

Problems of modern biology : Biology because of its central position among the sciences has the greatest problems. The phenomena of life is the meeting place for conceptions that arise from exact sciences on one hand and social sciences on the other. Biology has borrowed the mechanistic view from physics, vitalism from psychology and selection from sociology. Its autonomous development is, however, essential to accomplish its mission as a science concerning and mastering the phenomena peculiar to its own field, and for contributing to basic concepts of the world. These significant new conceptions have developed during the last few decades and there is more stress on integrated approach in the investigation and teaching of biology.

The experimental method has gained much more importance in recent times for solving the serious problems facing the biologist today. Even the areas of biology which have classically used descriptive methods are now turning to experiments. The problems of today are in great need of help from biochemistry in the field of relationship of materials from cellular chemistry, from physics for energy relationships and from biological experimental methods for the control and integration system of plants and animals.

Biology offers several difficulties in its study, the living system being far more complex than any physical entity. The location of chemicals and large molecules and arrangement of these in a particular pattern is a necessary condition for life. It is very difficult to understand these patterns as the chemicals change location with time. The whole organism is considered to be something more than mere sum total of its parts. Living material is variable and its response during experiments may be influenced by a great variety of factors. The best that can be done is to reduce the influence of these factors to a minimum.

Relationships between physical and biological sciences : Physical sciences have provided biology with powerful tools and methods for measurement and analysis of living phenomena. The spectacular recent advances in the physical sciences have given an impression that biology is now an unresolved form of chemistry and physics. Some biochemists go to the extent of saying that modern science has wiped out the border line between life and non-life. But a large section

of scientists reject this view and still hold that life is something unique from non-life.

The powers of physics and chemistry cannot be brought to bear on the study of life if biology itself is allowed to decline. There is thus a great need to discover how best we can combine chemistry and physics with biology so that the integrity of each discipline is retained to effectively help in solving the problems of biological function.

Biology today and tomorrow : An explosive increase in biological knowledge has taken place in last decade especially in the fields of molecular and cell biology. The use of the electron microscope and radioactive traces have made possible discoveries even beyond our expectations.

Cell theory : Much biological research work today is concentrated on the cell for here lies the key to understanding many of the complex problems of life. Growth, reproduction, heredity, embryology and physiology : all are based upon activities within the cell. We have learned much through these studies. Fundamental similarities in the chemical constituents and metabolic activities of all cells have been established. The activity of an organism as a whole is considered to be the sum total of activities and inter-actions of its independent cell units. Some of the outstanding problems that face cell biology today include : how transformations of groups of cells into tissues and organs are controlled, how the cell membrane can exhibit control over what enters and leaves the cell, how energy is utilised to more molecules or ions against diffusion gradient, how the kidney cell sorts molecules and ions and how plant cells continue to absorb mineral ions even after they are more concentrated inside the cell, etc.

Evolution heredity and genetics : When we trace the history of evolution we find that there was a gradual emergence of living beings from inorganic materials and the slow modifications of these beings produced millions of different patterns of structure so that we have great diversity in plant and animal kingdoms. The discoveries of Darwin and other biologists succeeding him have revolutionised the ideas of origin of the human race. Darwin's theory of natural selection gave clues to the struggle for existence,

survival of the fittest and inheritance of advantageous characters by off-spring of the surviving individuals. This concept had a central role in the biological theory of the past century and, with suitable amendments of subsequent discoveries in genetics and evolution, is held by most biologists of today.

The unique knowledge about the property of life that living matter is generated within the cells was followed by the discovery of genes, the architects of heredity in the bodies of all plants and animals. Genetics, the branch of biology dealing with heredity is considered to be a nucleus to biological sciences. It has developed most rapidly in the first half of the 20th century and has most profoundly affected the development of biology as a whole. The great advances made in genetics altered the outlook of many biologists in their own primary fields. The acceptance of Mendels' theories forced a reassessment of views on reproduction, metabolism, development, acquisition and maintenance of the specific form.

Genetics deals with the organism at three levels : at the level of population, the individual and cellular level. At the lowest level lies the molecules of DNA organised in genes and chromosomes or analogous structures. The process at this level is responsible for all levels i.e. self replication or duplication of macromolecules with its accompaniment of mutation. Genetics beginning with the individual level moved first to form population genetics, evolutionary genetics, ecological genetics, etc., and finally to the level of chromosomes and molecules.

How the new genes arise in the system of continuum has been studied by experimental approach, which is considered to be a new kind of genetics called molecular genetics. The demonstration of artificial transmutation of genes and the discovery of the transfer of specific transforming material from one bacteria to another is significant. The material transferred is DNA, which is a specific hereditory material capable of transmitting a naw hereditary property without sexual crossing. The demonstration of the model of molecular structure and manner of replication of DNA by Watson and Crick 1953 was followed by the discovery of the pathway, leading to biosynthesis of DNA.

The work at both levels, i.e. one beginning with the organism and other with hereditary material can now be utilized in attacking the great unresolved problems of evolution and development.

About future research in genetics, it is predicted (Anonymous, 1966) that an understanding of the genetic code and related aspects of genetic control would have a profound effect on society. The genetic technology is expected to permit the rapid development of a superefficient fibre and nutrient plants and of plants and animals adaptable to growth in currently unsuitable environments, resistant to diseases, etc. Also the direct chemical control of the genetic structure can be expected too pen up the economic synthesis of specific proteins in bulk as a food source.

Photosynthesis : In the past twenty years, marked progress in understanding photosynthesis has been made and the secret of the chlorophyll catalyst action and related biochemical and biophysical reactions may soon be solved. A major breakthrough in this regard will be the development of means of mass production of chlorophyll together with photosynthetic enzymes.

Enzyme and metabolism : The concept that metabolism in all living organisms is mediated by a specific organic catalyst, an enzyme, synthesized by living cells has gradually been crystallised since 1815, when Krichhoff prepared an extract of wheat which would convert-starch to sugar. It has been established that the substance undergoing a chemical reaction (the substrate) unites with the enzyme to form a specific enzyme-substrate complex. In this way enzymes control the speed and specificity of essentially all the chemical reactions of living things.

The metabolic processes are regulated so as to maintain the internal environment of the cell as constant as possible. External conditions tend to produce changes. Living organisms constantly adapt in ways which tend to resist the effects of these changes and keep the maternal environment constant. This tendency toward constancy is called *homeostasis.* In the course of evolution higher organisms have developed a greater degree of homeostatic control than the lower ones.

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The unique knowledge about the property of life that living matter is generated within the cells was followed by the discovery of genes, the architects of heredity in the bodies of all plants and animals. Genetics, the branch of biology dealing with heredity is considered to be a nucleus to biological sciences. It has developed most rapidly in the first half of the 20th century and has most profoundly affected the development of biology as a whole. The great advances made in genetics altered the outlook of many biologists in their own primary fields. The acceptance of Mendels' theories forced a reassessment of views on reproduction, metabolism, development, acquisition and maintenance of the specific form.

Genetics deals with the organism at three levels : at the level of population, the individual and cellular level. At the lowest level lies the molecules of DNA organised in genes and chromosomes or analogous structures. The process at this level is responsible for all levels i.e. self replication or duplication of macromolecules with its accompaniment of mutation. Genetics beginning with the individual level moved first to form population genetics, evolutionary genetics, ecological genetics, etc., and finally to the level of chromosomes and molecules.

How the new genes arise in the system of continuum has been studied by experimental approach, which is considered to be a new kind of genetics called molecular genetics. The demonstration of artificial transmutation of genes and the discovery of the transfer of specific transforming material from one bacteria to another is significant. The material transferred is DNA, which is a specific hereditory material capable of transmitting a naw hereditary property without sexual crossing. The demonstration of the model of molecular structure and manner of replication of DNA by Watson and Crick 1953 was followed by the discovery of the pathway, leading to biosynthesis of DNA.

The work at both levels, i.e. one beginning with the organism and other with hereditary material can now be utilized in attacking the great unresolved problems of evolution and development.

About future research in genetics, it is predicted (Anonymous, 1966) that an understanding of the genetic code and related aspects of genetic control would have a profound effect on society. The genetic technology is expected to permit the rapid development of a superefficient fibre and nutrient plants and of plants and animals adaptable to growth in currently unsuitable environments, resistant to diseases, etc. Also the direct chemical control of the genetic structure can be expected too pen up the economic synthesis of specific proteins in bulk as a food source.

Photosynthesis : In the past twenty years, marked progress in understanding photosynthesis has been made and the secret of the chlorophyll catalyst action and related biochemical and biophysical reactions may soon be solved. A major breakthrough in this regard will be the development of means of mass production of chlorophyll together with photosynthetic enzymes.

Enzyme and metabolism : The concept that metabolism in all living organisms is mediated by a specific organic catalyst, an enzyme, synthesized by living cells has gradually been crystallised since 1815, when Krichhoff prepared an extract of wheat which would convert-starch to sugar. It has been established that the substance undergoing a chemical reaction (the substrate) unites with the enzyme to form a specific enzyme-substrate complex. In this way enzymes control the speed and specificity of essentially all the chemical reactions of living things.

The metabolic processes are regulated so as to maintain the internal environment of the cell as constant as possible. External conditions tend to produce changes. Living organisms constantly adapt in ways which tend to resist the effects of these changes and keep the maternal environment constant. This tendency toward constancy is called *homeostasis*. In the course of evolution higher organisms have developed a greater degree of homeostatic control than the lower ones.

Some of the unresolved problems are—How do organisms measure temperature and time ? How can the hypothalmus control temperature so precisely in mammals and birds ? How does it measure temperature and what does it use as a reference point ? How do plants and animals measure the length of day or night in order to respond to seasons ?

Inter-relations of organisms and environment : One of the major unifying concepts of biology today comes from the field of ecology. From detailed studies of communities and plants and animals in a given area, the generalisation has been made that all the living things in a given region are closely inter-related with each other and with the environment. This generalisation includes the idea that particular kinds of plants and animals are not found at random over the earth but occur in inter-dependent communities of producer, consumer and decomposer organisms together with certain non-living components. Why certain plants and animals comprise a given community, how they interact, and how man can control them to his own advantage are major research problems in ecology.

Applied biology : The domestication of animals was one of the essentials in the development of civilization. The domestication of animals led to the increase of population and the strengthening of tribal habits and directly gave rise to that division of labour without which civilized life is impossible.

This branch of biology, viz. animal husbandry and veterinary science had the benefit of scientific research in addition to the knowledge and experience first handed on by word of mouth.

The principles underlying the animal sciences covering biological and physical sciences have been employed to select and breed increasingly more desirable animals to better understand reproductive physiology and thereby improve fertility and enhance reproductivity, and to provide well balanced and adequate rations which have decreased mortality of the young and provided the nutrients for fast and efficient growth and production.

Some fundamental questions about nutrition being

explored, when answered, will result in more and better animal products at lower costs.

It has been often felt by teachers of modern biology that an integrated approach, both between various subjects and within a subject, has been lacking. The need for sound basis of physics, mathematics, and chemistry for understanding of biological phenomena cannot be over-emphasized.

Within the science of zoology or botany, the integrated approach is equally essential While teaching, the emphasis should be on the function rather than the structure. Therefore, the study of individual body systems is not sufficient. Their interconnecting links involve various systems separately and that knowledge reunites at the functional level and forms the entity of life science. Just as a study of individual cells, even though useful and extremely interesting, cannot convey the meaning of life of the individual to which it belongs, so also the familiarity with various body systems is to be integrated. The body as a whole and its functions are to be described with the help of body systems. The studies of body systems, thus, will be as interesting and as essential as the study of the functions of an individual cell. Greater emphasis is, therefore, being laid these days in universities to make the desired connecting links in various systems as well as various subject specializations in a given science, let it be zoology or botany. This approach is important both at the time of lecturing and conducting the practicals and is desired to be incorporated in all university textbooks.

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Glimpses of the Plant Kingdom

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Man found this earth covered with a green mantle of life called vegetation. Even over the 500 to 1,000 millennia of pre-human and pre-*sapiens* existence, a food-gathering technology had been developed and handed down to the new generations. From the luxuriant growth of plants man obtained, directly or indirectly, all the food he needed, covering for his body, materials to build his house and even the oxygen to sustain his very life.

Spontaneous generation : There are about 350,000 different species of living plants scattered all over the earth and living in a variety of environmental conditions. Within this vast assemblage, the lower and higher plants, the temperate plants, the lush tropical plants and the plants growing in the Sahara, and other deserts. There are tremendous variations in structural and functional characteristics. The panoramic view of the vegetation in his surroundings had from the very beginning marvelled man and occupied his attention. To the casual eye, however, this presents a rather confusing picture and man through the ages has made great efforts to find some system which may connect and relate all members of the plant kingdom in an orderly and understandable way. The great Greek thinkers, Aristotle and Theophrastus, believed in the spontaneous generation whereby plants could arise through an independent act, without the intervention of parents. This idea with miraculous overtones held the imagination of people till the nineteenth century. The magic of these great names was such that very few people dared to question this belief. Many inquiring minds,

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however, kept probing the matter and the publication of the book, *Origin of Species* in 1859 by Charles Darwin at last persuaded the biologists to discard spontaneous generation for organic evolution of plants. The scientists have gathered much evidence to justify this concept that all modern plants were derived from very primitive parents through a process of gradual modification.

Unicellular organisms : From the point of view of evolution, it seems easier to visualize a single cell evolving into complex plants than it does to imagine a group of chemical substances evolving into a cell. In all probability, the first step was more difficult but unfortunately there is no way of checking that matter, for the events leading to a cell have certainly left no record that could be found on the surface of the earth. The study of early evolution, therefore, really amounts to educated guesswork and surmise.

Just how the first living organisms upon the earth were derived from non-living materials, already present, remains a mystery; for man has not himself been able to produce life from non-living materials or to discover anything of the sort occurring spontaneously in nature today.

Considering some most reliable clues, scientists generally agree that life began with one or a very few simple types of organisms over two thousand million years ago. By a process of reproduction, these early organisms perpetuated and multiplied their kind. For the most part, the offspring resembled their parents but occasionally one of them happened to differ. This original difference may have been very slight, but, because it was perpetuated, it provided a starting point for greater changes. A few generations later, one of the offspring of the new type changed further, the second change being added to the first. Thus, by an accumulation of small changes over a great many generations, there emerged at last a type of organism that differed to a significant degree from its original ancestor. Meanwhile, other lines of offspring from the same ancestor may well have perpetuated themselves without modification. Evolutionary divergence, thus, started taking place giving rise to new types of plants.

Multicellular forms : How the single-celled organisms progressed into multicellular forms is again shrouded in mystery.

There is absolutely no fossil record of this transition but there is no doubt that this great step forward occurred in an aquatic environment. There were many advantages due to the increase in size: for the unicellular organisms were changed to multicellular forms. Their living conditions changed also. There were new methods of taking in food, new possibilities of locomotion, new physical habitats that could be entered and many other innovations. The step from unicellular to multicellular form was full of the same bright prospects that opened up to more advanced organisms when they discovered land. Once this was accomplished, life on earth was not the same again.

Algae—the primitive members of plant kingdom : The algae form a very large and heterogenous group. They include many single-celled and a number of related multicellular forms. These range from single filaments, as in *Spirogyra*, to huge and massive seaweeds. The green algae consist of a number of different evolutionary lines such as *Spirogyra* and numerous others that are perfect examples of blind alleys in multicellularity, as well as the main line which leads to higher plants. This successful line is a filamentous one where a beautiful series of progressively more complex compoundings of filaments produce an increasingly bulky plant. As the size increases, the filament becomes modified to rectangular or truncate cells that are brick-like in appearance with an increase in size, the power of growth no longer is possible in all the parts; the older parts remain rigid as the new ones expand. In the green forms of algae, these meristems progressed further and gave rise to the higher plants.

The algae adapted themselves to an almost entirely aquatic environment. They are found in fresh water and in the sea and they are so abundant that ninety per cent of all the photosynthesis in the world is performed by algae. Although a few scattered cases of peculiar adaptations of small, often . exist as terrestrial forms generally, the have not successfully conquered land. The however, is that they are the progenitors of are the higher plants.

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place in the sum for photosynthesis and was free from competition with other forms. Great and unprecedented opportunities for the progress of plants lay ahead. The simple *bryophyta*, particularly the mosses, overcame the problems imposed by terrestrial existence by remaining small and keeping close to moist places. Their small size posed no great problem for finding support and drying-out was prevented by the immediate high humidity near aquatic surroundings.

Good fossil records of the first truly vasuclar plants which appeared on the crust of the earth are available. It is certain that a general trend of increase in size was accompanied by the progressive specialization for terrestrial existence. These specializations were essential for complete conquest of land. The waxy cuticle and stomata developed to prevent or control water loss; the formation of fibres in the vasular bundle resulted in a support system; the root system tapped water and salts in the ground; the internal and external leaf construction was an effective sun-trapping system; the elaborate vascular system, xylem and phloem, developed for transport of water, salts, and the products of photosynthesis.

The sequence of groups of vascular plants and their period of climax in the early earth history are preserved in fossils and are well-known and established. There is a steady sweep up through the ferns, thelycopods (*Selaginella*) the gymnosperms and the angiosperms. Each of the earlier groups was master and ruled the forests of the earth. They attained great size and in all ways seemed perfection. These earlier groups were effective in coping with a particular environmental situation. In the process, they gave rise to forms which were even better able to do so. Small changes, in a world of competition, gave large advantage in the struggle for existence.

One of the more notable improvements in the structure of the vascular plants occurred in the reproductive system. In ferns, fertilization takes place in the delicate, algal-like gametophyte, which is dependent upon a damp, boggy spot for growth and since the sperm is motile, this phase of the life cycle is still aquatic. The gymnosperms are the first to successfully achieve dry fertilization. In conifers, the sperm

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is pollen and can be carried by wind. The gametophyte never leaves the plants; it is held safely within the cones so that external water is not needed for reproduction. Many refined improvements also took place in angiosperms and remarkable devices evolved to attract pollen-carrying insects.

Acquiring such characters, the higher plants have become much more versatile in adaptations to a variety of environments. They have established themselves in marshy lands and they have made homes in the great Sahara. They abound in high, cold mountains and they provide food and shelter to the people in the flat lands. Conquest of new environments are made constantly and new forms are evolved which are more effective and efficient in dominating particular environment.

Selective response to opportunities in environment : In the thick rain forests of the Amazon, a young plant sprouting in the dark forest atmosphere has a poor chance of survival unless it can breakthrough the canopy overhead. Some trees such as the Brazilian fig (*Ficus* species) have solved this problem by climbing on other tall growing trees. Birds and the fruit-eating bats deposit the seeds of these trees on the branches of the *victim*. The young seedlings produce two types of roots; one growing around the branches or the main stem of the supporting tree, the other reaches the forest floor through the air or along the tree trunk. The roots establish themselves in the soil and the growth of the riding figs becomes fast. Their roots rapidly thicken and harden around the trunk of the victim. The whole of this growth forms a mesh which envelops the host tree, preventing its trunk from expanding and subsequently squeezing it to death. There are many other examples of such stranglers in many parts of the world. Due to nature's selection of useful hereditary modifications such members of the plant kingdom possess amazing adaptations for survival.

The plants in a desert have overcome the survival problem through the seed germination mechanism. There are plants whose seeds would germinate only when a definite quantity of rain comes during a particular period of the year. F. W. Went reports that if Death Valley in California is to bloom in the spring, a rain—well over an inch—must come during the preceding November or December. A similar

quantity of rain in any other month is ineffective. The seeds of such plants contain chemical inhibitors which are washed down by the right amount of rain water. Seeds of some other desert plants do not germinate because of the presence of appreciable amounts of salts. They germinate only when a heavy rain leaches the salts down.

The seeds of certain shrubs such as the smoke tree germinate only in the beds of dry rivers. Their seed coats are so hard that only a strong force can crack them. This force is provided in the nature by the grinding action of the mudflow. It is interesting to note that the seedlings of the smoke tree germinate not under the parent shrub but about 50 to 100 yards downstream. This is the critical distance. The seeds closer to the shrub are not ground enough to open and the seeds which have been carried very far get crushed. As Wents puts it, the selection on the basis of germination has endowed these plants with a remarkable variety of mechanisms for germinating and at the same time it has made them slow to germinate except under conditions ensuring their later survival.

Killers and the benefactors : We are all familiar with the leguminous plants. They are the great benefactors among members of the plant kingdom. Such plant leave nitrogenous compounds in the soil which are used profitably by other plants. There are plants, however, which poison the soil for many feet around thus preventing the growth of other plants thereby monopolizing the local water supply. The wormwood (*Artemisia absinthium*) is one of such plants. The leaves of brittle bush (*Encelia farinosa*) also contain a toxic substance. When these leaves fall on the ground, their toxic action severely retards or even kills the nearby plants which come into contact with them. There are many other such plants which have solved the competition problem by the chemical means.

From forest to field : Food was the major problem of man even before the dawn of history. He hunted, fished in the streams and women of the tribe gathered a few edible wild plants. He ate berries for sugars and vitamins, nuts for oil and roots provided him carbohydrates. For a million years, this routine went on. Less than 10,000 years ago domestication of plants began on the forested uplands of

south-western Asia. Keen observation that the grain-bearing grasses grew up where seeds had fallen led to one of the greatest achievements of man—planting and harvesting of crops. The food producing revolution had begun with wild wheat, barley and other food plants.

With the domestication of plants (and animals) man became 'civilized'. He started living in large groups in villages instead of caves. The areas around these villages became rich in nitrogen due to piling up of rubbish. Naturally, the nitrogen-living plants such as hemp were cultivated by man in such surroundings. Some other plants which grow as weeds in nitrogen-rich soil could have been domesticated at that stage. Those members of the plant kingdom which could serve more than one purpose must have received more attention from early man as compared with those plants which could be used only for one purpose. Hemp is one such plant; it is a drug plant, its seeds yield oil and its fibre can be utilized for many purposes. Many tree plants were domesticated because they gave fruit for eating, wood for fuel and like the mulberry, leaves for rearing silkworms. Coconut is another example which has provided many things to the people living on the tropical sea-shores.

The plants with edible roots were perhaps the first which lent themselves well for cultivation by the early nomadic man. They stored food underground and could be dug up easily by the kind of tools man had at that time. *Colocasia* is thought to have been domesticated in Asia. Cereals like millets, wheat and rice were also grown at about the same time. As the domestication of plants began in many parts of the world, American-Indians started growing maize. In the Asian tropics, rice become a provider. Sorghum and millets became established in Africa. Rye was taken along as a weed when wheat travelled northward over Europe from the Mediterranean region. Due to climatic factors prevailing in the northern regions, rye out-yielded wheat and was selected as a cereal on is own right.

Origin of cultivated plants : Vavilov, the famous Russian Botanist, made numerous trips to various parts of the world and conducted work on genetics, chromosomes and anatomy of plants. He published his work in 1926 outlining the centres of origin of cultivated plants. The eight principal

regions of original as described by Vavilov are :

1. *The Chinese Centre of Origin :* This is the earliest and largest independent centre of origin of cultivated plants. Cereals such as broomcorn millet, Italian millet, Japanese barnyard millet named oats, hull-less barleys, buckwheat, soybean; various species of bamboo and surgarcane; Chinese artichoke, wild rice, *colocasia*; camphor tree, opium poppy; rhubarb, lettuce; pear; peaches; apricots and some citrus species originated here.

2. *The Hindustan Centre of Origin :* Rice, sorghum, chick pea, mung, beans, cowpea, eggplant, Indian radish, sugarcane, several species of cotton, hemp, black pepper, mango, orange, tangerine, citron, sour orange, sour lime and indigo originated here.

3. *Central Asian Centre of Origin :* This region includes Punjab, North West of Pakistan, Kashmir, Afghanistan, Tadjikistan, Uzbekistan and Westrn Tian-Shan. Common and club wheat, rye, pea, lentil, flax, sesame, cotton, cantaloupe, carrot, radish, garlic, spinach, pistachio, apricot, pear, almond, grape, apple and English walnut originated in this region.

4. *The Near Eastern Centre of Origin :* Some species of wheat, two-rowed barleys, rye, some oats, alfalfa, rape, mustard, cabbage, onion, fig, pomegranate, apple, cherry, grape, almond, hazelnut and pistachio nut originated in this centre of plant origin.

5. *The Mediterranean Centre of Origin :* Some species of wheat and oats, coarse-grained barley, white and crimson clover, flax and mustard, cabbage and turnip, onion, garlic, chive, thyme, peppermint, hop and lavendor have their origin in this region.

6. *The Abyssinian Centre of Origin :* Barley, some species of wheat, grain sorghum, pearl millet, chick pea, lentil, pea, safflower, sesame, castor bean, coffee, okra and vegetable mustard originated here.

7. *The South Mexican and Central American Centre of Origin :* Important cultivated plants which originated

CENTRES OF PLANT DOMESTICATION (AFTER VAVILOV)

in this area include corn, beans, many cucurbits, sweet-potato, some species of pepper, some species of cotton, papaya and avocado.

8. *The South American centre of origin :* Many species of potatoes originated here. Other plants such as large grained floury maize, lima bean, pumpkin, Egyptian cotton, tomatoes, guava and some species of tobacco also have their origin in this part of the world.

Plant introduction—today and tomorrow : Man crossed oceans to settle in new lands and build a New World. Wherever he went, he took plants along with. Plants were introduced to new countries from their native homes. Apples, peaches, plums and many vegetables have travelled around the world. Many plants completed the circle and were re-introduced in their home localities, much improved. Special efforts have been made during the last one hundred years to explore the far off lands to find fruits, nuts, vegetables and other plants of value. The introductions of plants, new species and new varieties from one part of the world to the other through the scientific cooperation on an international level are taking place everyday; thus holding great promise freedom from hunger and want.

Plants have provided man with countless amenities. We obtain from plants today our daily meal, beverages, wines and liquors, our clothes, houses, fuel, drugs, tanning materials and dyes. In short, the plants are the mainstay of our civilization.

During the last 10,000 years or so, we have cultivated plants for our needs. It was a tough job indeed. The tools were primitive, manures were scanty and the plants were low yielding. A farmer could not feed but a few months. Whereas the industrial revolution had freed the city dweller from back breaking work, his counterpart who worked with plants was bound to drudgery on the land.

But the things have changed now. The technological revolution has broken the servitude of man working with plants. Substantial gains have been made in agricultural technology to deal with plants in a better way. The application of the findings of science has made possible the

development of herbicides, better and more efficient fertilizers and pesticides; and chemicals for particular plant responses. Crop plants are shown by machines in soil prepared by tractors, weeds and pests are controlled by chemical sprays, the produce is harvested and brought to the packing houses by machines and sent to the cold storage for safe keeping. Better varieties are bred everyday and new important plants are introduced to feed and clothe the population in a better way. The foundations for better plants and better technology for the future are being laid today.

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Glimpses of the Animal Kingdom

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Difference between plants and animals : Animals are generally characterised by their dependence upon plants and other animals which they use as food: by their ability to move freely; by possession of nervous system through which they respond quickly to stimuli; and by growth occurring at all parts of the body. However, at the lowest level animals are difficult to differentiate from plants e.g. certain flagellates make their own food like plants and move as animals do. Thus the botanists call them plants and zoologists say they are animals. The only difference between plant and animal life at the lowest level is that the animal cell is enclosed in a delicate membrane and a cell wall is lacking. The latter is well developed and made of cellulose in plants.

Number and variety of animals : It is estimated that zoologists have already described 12,00,000 different species of animals. It is now well accepted that the simplest animal life originated on earth about 500 million years ago, and the large number of species which exist today have appeared through a slow process of evolution. The present day animals range from single celled microscopic organisms like the malarial parasite to the blue whale which is more than 100 ft. long and weighs more than 110 tons.

For convenience in study, the systematists or taxonomists have classified this big array of animals according to their phyllogenetic relationships. For instance, the scores of varieties of the common cat belongs to the species domesticus which along with other cats like tiger, panther, lion, leopard etc., belongs to the genus *Felis.* The genus *Felis* along with

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other genera to which the many carnivous animals like bear, dog, sea-lion belong are included in the order *Carnivora;* and this order along with other orders in which cats, dogs, horses, cows, hares, monkeys, squirells, camels and man himself, all of which have hair on body and suckle their youngones, fall in the class *Mammalia*. Several classes like *Mammalia*, (mammals), *Aves* (birds), *Pisces* (fishes), *Reptilia* (snakes & lazards) are grouped under the phyllum *Chordata* because all have a vertebral column in common. Like this there are 12 phylla into which the animal kingdom is divided. The more important among these are :

(1) Arthropoda (insects, crustaceans, millipedes, centipedes, spiders, ticks, mites, scorpions)—9,00,000 species.
(2) Mollusca (molluses—clams, oysters, mussels)—80,000
(3) Chordata (vertebrates)—40,000
(4) Protozoa—30,000
(5) Cnidaria (coelentrata—jelly fishes, corals, sea anemones etc.)—9,000
(6) Annelida (earthworms, sandworms, leaches etc.)—4,000
(7) Platyhelminthes (flat worms)—6,000
(8) Echinodermata (star fishes, sea urchins, sea lilies etc.)—4,000

Thus the arthropods which include insects, mites, spiders, scorpions, crustaceans etc., are the single largest phyllum and insects alone comprise 75 per cent of the total described species of animals.

Form and colour : The form and colour of animals varies not only between species but also within the species. Thus there are different breeds of dogs differentiated on the basis of form and colour. Even in the same organism the form of colour may vary greatly during different life stages. For example, the butterfly or a beetle passes through entirely different egg, larval and pupal stages. Certain harmless animals mimic some dangerous or poisonous animals, or may have protective colouration. There 'are others like the chamelion which can change their body colour to match the changed surroundings. This has occurred through evolution-selection for characters having greater survival

value. Thus, in recent years through industrial melanism, darker races of certain moths have appeared in industrial areas of England.

Physiology : Animals are diverse not only in form, structure and colour but also in physiology. Actually the differences in form demand different activities. Thus, animals differ in methods of movement, ingestion, digestion and egestion of food and other physiological activities.

For example, the camel drinks huge quantities of water and can then live for 7 to 8 days without water and may lose 22 per cent of its weight without decline in health. However, man becomes deaf and mad if he loses 10 per cent of his weight and may die if he loses 12 per cent within a short period. This can happen because at 122°F, a temperature met with commonly in the deserts, man may lose 1 litre of sweat in one hour.

Certain insects like locust eat several times their body-weight within 24 hours and yet others like khapra larvae can live without food for over two years. Others can live on very dry food material utilizing metabolic water.

Habitats : The earth can be divided into a number of habitats like rivers, ocean depths, deserts, forests, pastures, etc. In each habitat a great variety of animals live. For example, in a pasture there is a cow; there are insects on the grass and cow; birds preying on insects; other birds preying on insectivorous birds; parasites of insects, birds and cattle and so on.

Adaptation : Animals have adapted themselves very well to the habitat they live in. Actually, animal life characterizes certain life zones or altitudinal belts from the foot-hills to the top of high mountains. In a given season the approximate temperature at a certain place depends upon its elevation and temperature at sea level; e.g. when temperature at sea level is 80°F, it is 65°F at 4,500 ft., 60°F at 6,000 ft. elevation and 13°F at the summit of Mt. Everest. It is possible to estimate the altitude of a place by observing its animal life. Likewise the activity of certain animals is correlated with weather. For example, the chirping sound of the crickets is correlated with temperatures and using

certain formulae it is possible to determine the temperature from the number of chirps per minute.

Migration : Not only are animals adapted to local conditions but they can hibernate in bad weather for prolonged periods or migrate to favourable places. The migration may be from higher hills to lower hills during winter and vice versa in summer, or it may be over several degrees latitude to reach analogous life zones on mountains situated in the warmer region. For instance, the woodcock migrates from the Himalayas to Nilgiris in the winter. The birds may cover long distances of 200-1,500 miles in a single hop. The monarch butterfly in USA also has a true migration because the same butterflies that come to the south in autumn return to the north in spring, and a butterfly covers 1,500 to 2,500 miles distance in her life time. Many other insects also take along flights e.g. locusts have been seen over the sea at about 1,000 miles away from the sea shore. Not only insects can fly fast up to 25 m.p.h. but they can also hover at a place like a helicopter. However, they have not been seen to fly as high as the birds because some birds have been sighted at 29,000 ft. elevation. Besides, flight and speed the broad and high jumps by some lowly animals have fascinated man. For example, the grasshopper makes a broad jumps of 300" and the rat flea jumps 12" high. According to these standards, for his size, man should make a broad jump of 80-90 feet. and a high jump of 1,200 ft. to equal the feat of the insects.

Breeding activities : In certain animals there is no affection between the male and the female. For example, the female preying mantid kills and eats the male after mating. In others, however, there is considerable amount of love, a long courtship and repeated mating. For instance, the lion is an ardent lover. The mating lions isolate themselves and for a few days stay completely aloof from others of their family. They have been seen to mate frequently at intervals of every 20 minutes and one zoo lioness mated 360 times in 8 days.

The number of eggs or young laid is extremely variable. For example a female oyster may lay up to 60 million eggs. In some animals e.g. the amoeba maturity is achieved in three days and there is rapid reproduction, but in others like

the 17-year cicada, the young ones become mature after a very long period.

Reproduction among animals may be a sexual as in amoeba, or sexual. While in most insects reproduction occurs after mating, but there are insects in which males are completely lacking or are present only during certain periods so that either reproduction is completely agamic or there is alternation of gamic and agamic generations. Again some animals lay eggs e.g. birds and reptiles while others like mammals produce young ones. However, some primitive mammals e.g. platypus lay eggs but suckle their young ones. The size of the egg itself is very variable in animals. For instance in case of ostrick which stands 8 ft. high, weights 200 lb., has a 12 ft. stride, runs as fast as a horse, the eggs weigh 4 to 5 lb. each.

Certain animals lay the eggs and leave them unprotected. The koel is very callous as it lays its eggs in the nest of the crows. In the Surinam toad the male places the eggs on the back of the female where a lidded pouch arises for each egg and the egg develops into the adult form in it. Certain snakes, most birds and earwigs take care of their eggs. However, the maternal instinct is highly developed in the great hornhill. This bird lays its eggs in a tree hollow and incubates them. It shuts herself in with the eggs by closing the hole with its excreta. Sometimes the male bird makes a wall out of mud. The male bird brings the food and feeds the female through a small hole and also keeps a watch over the nest. The stickle backs (fish) make a nest of water plants. The females lay eggs in the nest. The male guards the eggs and also protects the young after hatching. Wasps paralyse larvae and provide these as food for their young and bees feed pollen and nectar to their young ones.

Social life : While certain animals live alone, others live in complex societies. The social system among ants, bees and wasps has been studied in detail.

The ants may have slaves. They keep and tend aphids as cows. Some ant workers may be prisoned and used as honey pots. Harvester ants store grains and dry them when needed for long storage. The leaf cutting ants are expert at growing fungi on which they feed.

Fishes : There are about 30,000 species of fishes. Although generally speaking fishes cannot live outside the water, yet they have wide adaptations. Sea robins can crawl at the bottom of the sea, some fishes can burrow in the sand or mud; flying fishes glide distances in the air, eels migrate through grass and climbing perch creep from pond to pond over the mud. Star gazers have electric cells in their head. They can give a strong shock to an animal or person and it is used to paralyse the prey.

The culture of man has depended upon animal life especially the animals that he has domesticated. He has taken advantage of the existing animals and also produced by inter-specific breeding animals that are more useful e.g. DZO (yak-cow), mule (mare-donkey) etc. These animals are adapted to conditions in which either parent lives and are also stronger than either parent. Man has also improved the quality of certain other animals like the honey-bees and the silkworm by selective breeding. Thus, the diverse animal kingdom is gradually becoming more and more diverse through the natural process of evolution and also artificially controlled breeding and selection.

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Physical Sciences as Foundations of Biology

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Ph.D. (J. Hopkins)

Mathematics and physics occupy a place of pre-eminence among the physical sciences and it is with the contribution of these sciences particularly with that of the latter that I will concern myself. I cannot claim to the exhaustive. Rather, I will pick up a few of the important contributions of these sciences and try to show how they have helped in furthering the cause of the biological sciences. These sciences have contributed most significantly by evolving fundamental concepts of matter and energy and by the development of accurate physical methods of measurements.

The science of pure mathematics can claim to be the most original creation of the human mind. By mathematical deduction we arrive at ideas, which cannot be easily conceived by perception through senses. When we think of mathematics, we have in our mind a science devoted to the exploration of number, quantity and geometry etc. Among the earlier mathematicians may be mentioned the name of Pythagoras, who lived in the 6th century before Christ. He studied geometry and discovered the general proof of the remarkable theorem about right angled triangles. Pythagoras was followed by Plato who extended and refined his ideas. In the next two thousand years till the 17th century mathematics made tremendous strides. The science of trignometary was developed and the discovery of integral calculus could almost be anticipated. The Asian thought had contributed the Arabic arithmetical notation and Algebra. The seventeenth century was an age of great physicists and great

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philosophers. During this great period of Galileo, Descartes, Spinoza, Newton and Leibntz, mathematics wielded considerable influence in the formation of philosophic ideas. Without this progress in mathematics during the 17th century, developments in science would have been impossible. Mathematics supplied the background of imaginative thought with which the men of science approached the observation of Nature. The birth of modern physics depended upon the application of the abstract idea of periodicity to a variety of concrete instances. But this would have been impossible unless mathematicians had already worked out the various abstract ideas which cluster round the notions of periodicity.

I shall now give a brief account of the history of physics. In the first period, which extends from the earliest times about 1550 A.D., facts of physics were collected as a result of the observation of natural phenomena. Theories could not be developed because of the almost complete absence of experiments to test the correctness of such theories as were proposed. This period is, therefore, characterized by the absence of systematic experiment.

The second period extends from 1550 to 800 A.D. This period is characterized primarily by the development and firm establishment of the experimental method as a recognized and accepted means of scientific inquiry. The first physicist of real merit to be considered here was Galileo (1564-1542). He is aptly called the father of modern physics. None of Galileo's predecessors had given so much to experimental physics as he has done. By 1610 Galileo had made a telescope with the power of 30 diameters and with this instrument he had made a number of fundamental discoveries. He saw that the number of fixed stars was vastly greater than could be seen by the unaided eye. The work of Tycho Brahe and Kepler also belong to this period. Tycho was the experimentalist, the observer, who supplied accurate data, upon which Kepler, the theorist built a new theory of Planetary motion. The impetus given to science by the great trio, Galileo, Tycho and Kepler resulted in an ever-increasing number of investigators in the generations that followed. About the same time, a number of learned societies were formed in several European countries. The Linean society was founded in Itlay in 1603, the Royal Academy of Sciences in France in 1666, and the Royal Society for Advancement

of learning in England in 1662. Great strides in the field of magnetism were made by Gilbert, Kircher, Cabdo and Gellibrand. However, the most significant event of this era was the appearance of Newton on the Scientific scene. He was head and shoulders above all his contemporaries and his contributions to knowledge are incomparably greater than those of the other scientists of the past. Newton, whose work on optics arose out of an attempt to improve lenses, made notable contributions in this field. He made equally important contributions in the field of mechanics (Newton's Law of motion, with which every student of science is familiar) and mathematics. Huygen, a bitter opponent of Newton formulated the wave theory of light; Robert Boyle, the discovery of Boyle's Law; Leibnitz, whose calculus ultimately replaced Newton's fluxion's were some of the notable contemporaries of Newton.

The third period (1800-1890) is characterized by the development of what is now called "classical physics" in contrast with the quantum physics of the present century. From the experiments of Count Rumford and Joule, the present kinetic theory of heat was developed.

By 1880 quite a few physicists believed that all the important laws of physics had been discovered and that future researches would be concerned mainly with clearing up of some minor problems of details. They could not foresee that the world of Physics was on the threshold of a series of major discoveries.

The fourth period may be said to begin with the discovery of the photo-electric effect in 1887. The period of ten years beginning in 1895 was a period of great discovery. X-rays were discovered in 1895, radio-activity in 1896, the electron in 1893, the quantum theory in 1900 and the light quantum was discovered by Einestein in 1905.

The discovery of the electron : The most important of all the chemical theories is the atomic theory. In 1805 the English chemist and physicist John Dalton (1766-1854) advanced the hypothesis that all substances consist of small particles called atoms. Sir J. J. Thomson, a physicist (1856-1940) during the course of his experiments on the conduction of electricity through gases concluded that

electrons do exist. He measured the ratio of charge to e/m. The charge on the electron was measured in 1906 by R. A. Millikan ($4.77 x 10^{-10}$ coul/kg.).

Applications in the field of biological sciences : Early man was seriously limited in what he could to explore the mysteries of Nature. His casual observations were limited by the limits of human vision. The eye is unable to perceive objects with a diameter less than about 0.004″ or 0.1 mm. Living cells, the units of biological structure and function, are nearly always below this size. Accordingly, the singled cell micro-organisms are for the most part invisible to the unaided human eye. The very existance of the microbial world was unrecognized by man until the advancement of scientific technology, resulting in the invention of simple microscopes, at the beginning of the seventeenth century. The discoverer of the microbial world was a Dutchman, Antony Var Leenwen Lock, who combined great skill in construction of microscopes with keen power of observation and interpretation.

The modern spectrophotometer is vastly superior to the human eye. It can measure the wave lengths of light below and above the visible range for which the eye is totally blind. It thus helps man in virtually extending the range of his vision.

The earliest methods used for bio-assay of vitamins were tedious, cumbersome and time consuming. Vitamins present in micro quantities in food materials had to be fed for long periods and their quantities estimated from the quantitative assessment of effects they produced. The estimations were highly erroneous. It was the pioneering work of Sir Heilborn in evolving a spectroscopic estimation of vitamin A which gave a spurt to this technique and led to its wide spread use subsequently.

If the modern organic chemist can quickly know the structure of a vastly complex molecule, it is primarily due to the availability of physical tools developed by the physicists in the pursuit of their own research. Among the major tools may be listed the X-rays, I.R. and N.M.R. spectrophotometer and the Mass Spectrometer. First developed by Sir William Bragg (1862-1932), the penetrating power of X-rays now finds extensive use in medicine, agriculture and chemistry. The

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differaction of X-rays by crystals has permitted the determination of atomic arrangements in crystals and has thus contributed to the development of modern structural chemistry.

The structure of Vitamin B and Penicillin. which has been placed at the disposal of mankind for combating the harmful effects of bacteria, would have taken considerably longer, were it not for use of this technique by the famous X-ray crystallographer, Dorothy Crowfoot, who was awarded the Nobel Prize for this work.

Biogenesis : The modern biochemist not only knows the precise chemical nature of the vitamins, hormones, and other complex molecules of microbial and plant activity but also he has, by and large, succeeded in unravelling the pathway Nature adopts in putting these large and interesting molecules together. The mastry that the modern biochemist has acquired in the field of Molecular Architecture, has resulted in better comprehension of Nature by man. This task would have been impossible, but for the use of isotope-labelled compounds. It may be recalled that when radioactivity was discovered, the discoverer possibly had little notion of the great role that it was going to play in the field of biology.

The interesting fact that has emerged from the study of biogenesis is that the present diversity in Nature has resulted through the application of a few basic mechanisms. Nature prefers to evolve a multipurpose general tool suited for a number of relative jobs rather than to adopt a new tool for every new job. The paths adopted by Nature to synthesize the skeleton of a molecule of cholesterol (implicated in heart diseases and obesity) of natural rubber, of the essential oils used so extensively in modern perfumery, of polyphenols which impart colour to flowers, and of the antibiotic, terramycin, are all built up from a simple two carbon unit, the acetate. It is indeed amazing how effectively Nature economizes.

Study of viruses and the electron microscope : Viruses are the smallest biological units containing all the materials necessary for their own replication. Viruses may attack animals, plants or bacteria, the latter ones are called baterio-phages. In general, viruses consist of a core of nucleic acid

and an external shell of protein. The protein case serves as a protective coating and may assist in the penetration of the cell wall of the host. The viral nucleic acid enters the cell and diverts its synthetic apparatus to the production of a new complete virus.

Electron microscopic examination of purified TMV shows the individual particles to be rods or cylinders about 3000°A long and 75°A in radius. The molecular weight, as obtained by light scattering is close to 40×106.

An invention of the micrscope made possible the study of minute particles which could not be seen by the naked eye and thus brought about almost a revolution in the field of biology. The electron-microscope has pushed the limit of visibility still further so that today it is, almost, possible to see at the moIecuar level. X-ray diffraction has permitted a closer look at the detailed structure of the virus particle. The special organization is based on the helix. The RNA is coiled into a single helix of radius 4°A, which extends the entire length of the eparticle.

The examination of the architecture of the smaller viruses has required the use of special electron-microscopic technique. Using the shadow technique, it has been possible to observe the bumpy character of the viral surface. It has been shown that capsomeres of smaller viruses are arranged in an icosahedral pattern. Each of the 20 faces of the icosahedron is an equilateral triangle.

The science of genetics : The gene as an 'indivisible' unit of heredity occupies the same place in biology as the atom does in chemistry. The gene is to the geneticist what atom is to the chemist. Modern chemical researches based primarily on the work of physical chemists have unravelled the chemical nature of the gene. Though much indirect evidence concerning their nature had earlier been obtained from analytical data on the composition of their constituent bases, the final breakthrough in the field of nucleic acid came when Wilkens in England observed that DNA from different sources had a remarkably similar X-ray diffraction pattern, suggesting a uniform molecular pattern for all DNA. Based on this and other evidence, Watson and Crick suggested a double helical structure for DNA. This model can now

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rationally explain the phenomenon of duplication, recombination, transduction and mutation and has provided a sound chemical basis for understanding the transmission of hereditary characters. Further delineation of the fine structure of the gene, the description of recon and mutton in precise chemical terms and the development of the genetical code must be rated among the best achievements of human ingenuity.

Mutation provides, what has been called "the raw material of evolution". They are the ultimate sources of inherent variation on which evolutionary change depends. Similarly, the improvement of plants and animals is based ultimately on the genetic variation provided by mutational changes.

In recent years many types of ionizing radiations including thermal neutrons (atomic radiations) have been used to induce mutations in many kinds of crop plants. The presence of the genetic variation is important for progress in plant breeding. The potential power to increase variation in a species by artificial induction of mutations immediately offered attractive possibilities to the plant breeder. X-rays and other radiations are used to induce mutations in plants, and have also been used to effect gene substitution from alien chromosomes. This procedure involves interspecific crossing. Only limited progress had been made in the field of plant improvement by the use of X-rays. The full potentialities of these as well as other radiations in this field are yet to be realized.

Another field which has far reaching consequences for mankind is the harmful effects of ionizing radiations on human beings. Mankind stands the risk of complete extinction from radio-active fall outs. This is a very wide subject and I will not dwell further on it.

The rigid boundaries of yesterday separating various disciplines are in the process of rapid dissolution. From the debris of old disciplines, new ones are emerging which defy simple definitions. Today it is difficult to distinguish a chemical physiologist from a physiological chemist or a chemical physicist from a physical chemist or plant bio-chemist from a plant physiologist etc. The areas of

specialization are no longer sharply defined and there is a perceptive diffusion of scientific talent from one area of specialization to the other. Increasing collaboration between biologists and physicists had led to the development of biophysics—which aims at the study of biological phenomence by physical methods. Sir C. V. Raman, one of the greatest living physicists of the world, who was awarded a Noble Prize for his research in optics, is now busy in the study of the Mechanism of Human vision.

Calvin's work on the path of carbon in photosynthesis would have been inordinately delayed, but for the use of C^{14} which had been made available for such studies by the physicists. Calvin delinated the entire sequence of dark reactions initiated by the absorption of a quarta of light in a remarkably short time because he had at his disposal two powerful physical tools—the radioactive isotopes and paper-partition chromatography, the latter tool which has pervaded all disciplines of biological sciences was developed by two physical chemists as a result of their disinterested inquiry into the phenomenon of the partition of organic molecules in immiscible solvents.

Our understanding of the conversion of light into chemical energy would never have advanced to the current level except for the discovery of quantumn theory by the greatest physicists of all times—Albert Einstein. Today we are able to explain the phenomenon of selective absorption of light by plant pigments, the transmission of energy from one chlorophyll molecule to another within the chloroplasts because of researches in some of the fast developing fields of physics. The physical sciences have provided the biologists with a variety of new ideas and have placed powerful tools at their disposal which have extended the range of their study and made their researches more penetrating. Such study in depth of the biological sciences would have been impossible without the progress which had already been made in the field of pure physics itself. The best of the modern biologist would be ineffective if he was to be deprived of the benefits of modern instrumental techniques. Thus Physics and Chemistry must be given a place of prominence in the curriculum in Agricultural Universities for the continuous neglect of these subjects will prove ruinous to the development of the biological sciences in the long run.

Genetics as Nucleus of Biological Sciences

K. S. GILL*
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Genetics is a fundamental biological science which is in a state of exceptionally explosive growth. It has established close interrelationships with other biological sciences and now occupies a central position upon which all aspects of biology necessarily converge. Genetics, consequently, offers great opportunities for integration of students' knowledge of the various basic aspects of current and future biology.

The science of genetics is comparatively young. The history of development of genetic principles provides a case example among the biological sciences of how scientific knowledge evolves. It will, therefore, be interesting to go back into earlier studies and speculations to see how the background for modern genetics has evolved. The earliest recorded speculations about the nature of transmission of inherited characteristics comes from the Greek philosophers, Pythagoras Empedocles, and Aristotle, beginning about five centuries before Christ. William Harvey, Anton van Leeuwenhoek, Jan Swammerdam, and many other scientists of the seventeenth and eighteenth centuries advanced their own theories about the genetic concepts. In the nineteenth century, most of the scientists were concerned with the inheritance of acquired characters, natural selection, pangenesis, the germ plasm theory, and mutation theory. Heredity was explained by each scientist in his own way. However, there existed no theoretical insight that could lend coherence to the then existing experimental observations nor

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direction to further research. During the nineteenth century and in the midst of these controversies, Gregor Mendel (1822-1884), who was a priest at the Augustinian Monastery at Brunn, Austria, conducted experiments with the garden pea and eventually discovered the true secrets of genetic inheritance. He published his results in the Proceedings of the Natural Science Society, Brunn in 1866. On the basis of these results, he furnished an abstract and experimentally verifiable explanation of his findings. His theoretical contribution is credited as having launched the new biological discipline concerned with the transmission of potentialities from parents to offspring. He is now justifiably known as the "father of genetics." The findings of Mendel, however, remained obscure for one third of a century. In 1900, three scientists, viz., Tschermak in Austria, Hugo de Vries in Netherlands, and Correns in Germany, independently rediscovered the results of Mendel and proclaimed their importance to the biological world. This event of rediscovery of Mendel's results marks the real birth of the science of genetics as it is understood today. The name "genetics" was first used by William Bateson in 1906. Genetics is, thus, a mere baby of a science barely sixty-seven years old.

Since 1900, genetics has been developing rapidly and making quick interrelationships with various fields of biology. In the beginning up to 1940, the studies of heredity and variation were directed towards the elucidation of the trans*mission mechanism of heredity and significant contributions* were made to the understanding of basic genetic principles. Among the accomplishments, the concept of a unit of inheritance, the gene (the term coined by Johannsen) is the foremost. Without this basic concept, advances in genetics would have been unlikely.

The success of genetics came not from the simple confirmation of Mendel's postulates in different organisms, but from a series of complications and contradictions to these rules. The most important contributions to the genetic principles since Mendel's work includes : gene interaction, epistasis, pleiotropy; chromosomes as the physical basis of heredity, *linkage, crossing over; the process of mutations; discovery* that the nucleic acid DNA is the vehicle of hereditary transmission, the new molecular concept of the gene and its functioning; and the dynamics of the distribution and change

of hereditary elements in populations and in evolution. More and more problems connected with various fields of biology are being tackled on a genetic basis. As a result, genetics has been welded with other sciences and based on this symbiosis, it is now classified into various branches such as cytogenetics, biochemical genetics, physiological genetics, developmental genetics, immunogenetics, behavioural genetics, population genetics, and human genetics. Thus, the science of genetics which started at the level of the individual, is now concerned with the studies at the cell, gene, and the molecular level on the one hand, and to the level of populations, on the other hand. A similar hierarchy exists in biological sciences and these can also be classified at such levels of individual, molecule, and populations. It is with this background that the role of genetics as nucleas to biological sciences is being reviewed.

Cyto-genetics : Cytology is the first major branch of biology with which genetics became welded, to form a new field called ctyo-genetics. Early discoveries by the botanists and zoologists demonstrated that all the basic facts of life and reproduction are identical in animals and plants. Cytology, thereby, drew its discoveries from both the kingdoms and developed into an independent science. The cell was taken as the unit of structure and function. Genetics, by developing the gene concept, showed that the gene is an entity present in large numbers in the cell. It controls the specific properties of the cell but is strictly autonomous with respect to its specificity. This has upgraded cytology from its position of a specialized field to a most generalized centre of biological research. As a result of combined cytologic and genetic studies, outstanding achievements have been made and are being made. The discovery of location of genes in the chromosomes, the modes of inducing gene and chromosome mutations, and establishment of evolutionary relationships are among the outstanding contributions made by cyto-genetics. The use of electron microscope in cytogenetic studies has opened up new avenues of research in this field. Electron microscope studies of the lamp-brush and polytene chromosome have thrown new light on chromosome structure and gene function. With new cytogenetic techniques becoming available, numerous opportunities of research at this level are being offered.

Biochemical genetics : The interaction of genetics and biochemistry has yielded fruitful results in the study of the chemical basis of heredity and is pregnant with future possibilities. The biochemical approach to the study of the nature of the genetic material takes us back to the work of Miescher (1871). He studied the nuclei of pus cells (and, later, of fish sperm cells) and described a substance that he called nuclein. Avery *et al.* (1944) gave a first solid clue that genes are DNA rather than protein as has been assumed previously by many geneticists. This obvious genetic significance of DNA led James D. Watson and Francis H.C. Crick to work out the detailed molecular structure of DNA in 1953. This was the greatest milestone of twentieth century genetics, for this model of DNA proposed by Watson and Crick suggested answers to basic questions of biology, namely: 1. What is the nature of genetic information ? 2. How do genes replicate ? 3. How do genes control protein structure ? 4. What is the molecular basis of gene mutation, the basis of all organic evolution ? There still remain many problems to be solved connected with the chemical nature of the genetic material. The demands of genetics have, thus, succeeded in stimulating biochemical research of nucleic acids and proteins. The contact of genetics and biochemistry is full of promise.

Physiological genetics : Physiology embraces the broad spectrum of manifestations of life—the activities, functions, and other attributes of organisms; it includes far more than biochemistry per se, encompassing even developmental phenomena, structure, and organization. In formal genetic terminology, physiological genetics has particularly to do with phenotype and with the processes by which genotype becomes expressed as phenotype. The studies on alkaptonuria in man undertaken by Garrod (1902) marks the beginning of physiological genetics. He concluded that alkaptonuria is an inherited condition and it is due to an alternative pathway in the metabolism of nitrogenous materials, leading to the excretion of homogenetic acid rather than its further degradation product in the urine. The real breakthrough in such studies was made by the combined efforts of a geneticist and a biochemist, Beadle and Tatum (1941) using the mold Neurospora as material for their experiments. Since then physiological genetics developed with increasing rapidity. Great advances have been made

in our knowledge of metabolic pathways and in our understanding of the mechanism of gene recombinations and of the ways in which genes act. "One gene—one polypeptide" hypothesis is the outcome of this field of genetics. Although information on physiological studies is confined mainly to micro-organisms, yet an understanding of the implications of this branch of biology will surely act to intensify investigations of the fundamental bases of phenotype in higher organisms.

Developmental genetics : The study of developmental genetics covers a small portion of the wider field of physiological genetics. While the latter is concerned with all aspects of gene action, the former is concerned specifically with those aspects which are involved in the developmental processes. The developmental processes being concerned with embryology, the developmental genetics may be considered to be a wedding of embryological and genetic studies. The embryological studies have shown that development consists in a general way in a gradual narrowing down of prospective potencies from the equipotentiality of the whole to restricted but still manifold potenices of the parts, to restrictions within the parts. The multicellular organism is an integrated collection of very diverse cells, which all originate from a single cell—the zygote. From genetic studies, we know that all the somatic cells of an organism are derived from one cell through successive mitotic divisions. All the body cells thereby are with the same chromosomal and genetic constitution and are equipotent. These two sets of facts based on individual studies of embryology and genetics seem to be incompatible. The combined embryological and genetic studies are now aimed to answer the two main questions : 1. How do adjacent genetically identical cells give rise to cell lines that are morphologically, physiologically, and biochemically different ? 2. What role do the genes play in the mechanisms controlling development ? Many genetically determined abnormalities are being used by embryologists as useful study material with promising results. The complete analysis of the development of higher organisms still remains an unsolved problem. However, approaches seem to be at hand towards understanding the important aspects of this riddle. Present indications are that the genes act as essential catalysts of epigenetic development, whose regular transmission from generation

to generation is of prime significance in the control of developmental patterns. These advances are possible only in the conjunction of embryology and genetics.

Immunogenetics : The combined approach of genetics and immunology has been of considerable importance in studying various biological systems. Both genetics and immunology deal with highly specific and very numerous reacting substances, and in both fields, efficient methods are available for analysing the effects of these substances individually. So far as genetics is concerned, the joint attack led to some of the first advances in the study of the manner of action of genes. The beginning of this gene interaction dates back from the discovery of the human blood, groups by Landsteiner (1900). Early attempts at the clinical use of blood transfusion had frequently led to disastrous effects on the patient, so the practice had to be given up until after the work of Landsteiner and his followers was known and understood. Landsteiner found two distinct antigens in red blood cells of man and designated them as A and B. The cells could contain either antigen or both antigens, or they could contain neither. He also found that the blood serum always contained antibodies which would react with the antigens not present in the red cells. With this knowledge of A and B antigens and antibodies, we can understand why transfusion of one person's blood into another person will have serious consequences. Genetically a system of triple alelles with only one locus has been found to control the blood group systems. Such studies obviously have very useful medico-legal implications of blood group inheritance. Similarly other studies have been possible relating to other systems. Extensive work has also been carried out on the red cell antigens of cattle. These studies have led to striking developments in the field of immunogenetics.

Behavioural genetics : Behaviour is an important aspect of development of higher animals. In general, we are intrigued by such behaviour as learning and memory. How does the mammal, for example, learn to perform complex locomotor operations in response to some environmental situation, operations that are not part of an inherited, instinctive pattern at birth ? An example is the ability of rats to learn to ring a bell and switch off a light in order to obtain food. Behaviour is also important in providing

isolating mechanisms in speciation. Females of a particular species have been found to recognize their mates by their peculiar behavioural movements. An understanding of gene action in development enlightens the behavioural side of development of an organism. An understanding of behaviour, however, is not the primary task of a geneticist. In this regard, a new field of biology has been born, one that weds psychology and genetics and is named as "behavioural genetics".

Population genetics : Genetical approach at the population level has come to occupy a special place in biology. It represents interest in the process of evolution and in the improvement of domesticated plants and animals which strongly motivated the early students of genetics. Population genetics has united fields of biology such as genetics, ecology, paleontology, and systematics which tended to take separate paths. Ecology deals with the relations between plants or a plant community, or animals or an animal community and the various factors of their environment. It investigates the various structural and functional peculiarities that have appeared in response to the conditions prevailing in the locality. This work was, therefore, bound to come in contact with genetics and to be influenced by genetical facts and theory. Since the major constituents of the ecology of an organism are based on heredity, it becomes imperative to study the genetical mechanisms which permit the adaptation of the organism to its ecological environment.

Systematics is a science that deals with identification nomenclature, and classification of objects. The role of systematics is all prevading and fundamental. Before one could study plant structure, or the way plants grow, or accurately record the plants arround oneself, one had to know the names and characteristics of those plants. Systematics deals with the species and problems related to speciation. An understanding of the genetic basis of speciation has revolutionized our thinking about the concept of the species. It is now generally held that existing species have been produced through evolutionary processes. Species is now considered a conglomerate of distinguishable forms which are able to interbreed, if not separated geographically or ecologically. Thus, an understanding of the mechanics and principles of inheritance and the establishment of the

doctrine of evolution have exerted a great influence on systematics. In fact, genetics has made systematics a basic biological discipline.

Paleontology, the study of fossils, has great significance in evolutionary investigations. Since the whole process of evolution is understood in genetical terms, the subject of paleontology has also come to be married to genetics and has been greatly benefited by this marriage.

Population genetics, thus, provides solutions to many problems connected with ecology, systematics, paleontology, and genetics. The theory of population genetics started developing in the nineteenth century, but took a new start when heredity came to be considered in terms of genes. Hardy and Weinburg (1908) made the most important basic contribution to this science by providing a comprehensive theoretical treatment of Mendelism applied to randomly mating populations. Their concept of stability of gene proportions in a population has come to be known as the "Hardy-Weinberg Law". This law still forms the core about which the field of population genetics revolves today. Later important contributions have been made to the development of this science by Fisher, Wright, Haldane, and Dobzhansky. The theory has been developed on mathematical grounds, involving active participation of mathematics and genetics. We still need a more adequate theory of quantitative variability, based on generalizations, at the levels of physiological and developmental genetics, and also more understanding of the implications of population structures and ecological relations.

Human genetics : Man is one of the most unsatisfactory organisms for genetic study. The time interval between successive generations is long and individual families are too small for dependable determination of ratios, and desired test matings cannot be made on man for obvious reasons. The social implications of human genetics are so great, however, that the subject must be investigated. In spite of difficulties in human genetic studies, there are some advantages which encourage such studies to be undertaken. Having interest in ourselves, a great deal is known about the biochemistry, morphology, anatomy, and physiology of man. The science of genetics has important relationships with these

subject matters. The student of human genetics can, therefore, work with an unusually firm background of related knowledge in various fields.

The systematic study of the genetics of man was initiated by Francis Galton in 1865. With the rediscovery of Mendelian principles in 1900, a large body of data on human genetics have accumulated. In fact, great advances have been made in basic genetics through the study of human material, notably in connection with blood group and the biochemistry of haemoglobin variants. Simultaneously, genetics has made significant contribution in solving many human problems of parentage and genetic counselling. Humans, thus, offer challenging opportunities to genetic studies. Programmes have even been visualized to make genetic improvements in human race. Galton was one of the first to suggest the possibility of the genetic improvement of human populations and he introduced the word "eugenics" to designate this field of study and planning. There are still many obvious difficulties in carrying out any programme of eugenics.

Conclusion : It is evident from the above considerations that genetics has penetrated through the biological sciences from the level of the individual down to the level of the moelcule on the one hand, and up to the level of populations, on the other hand. Studies have further shown that genetic principles are much the same in higher organisms right down to the level of microorganisms. The universal application of genetic principles and its mutual relations with other biological sciences have played a great role in bringing all biological sciences into one coherent whole. All future developments in various biological disciplines will need active participation of genetic principles. Genetics has, therefore, become a nucleus of all biological sciences around which all of the biological sciences are making rapid progress. The impact of genetics is now being made on physical sciences and in space research. The science of genetics, therefore, must be understood by all those interested in problems connected, with living organisms.

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Ideas which changed the concept of Life on Earth

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Summary : The present article deals with the basic concepts on the origin of life on earth. The chemical events which gave the way to the formation of biologically active compounds (proteins and nucleic acids) and ultimately to the living cell are discussed. The formation of nucleoprotein molecules (simple form of vims) has been considered as the first type of molecular aggregation which exhibited properties of living systems on the primeval earth. The biological activity of the living cell is discussed in the light of modern findings.

Introduction : The past twenty years have been very remarkable in the history of life sciences. New techniques, new ideas and new theories have emerged from extremely imaginative and fundamental investigations in the field of chemistry, biochemistry and physiology which have changed altogether the basic concepts of life. With the help of electronmicroscope, it has been possible to study the fine structure of the living cell which is a fundamental unit of life. The study of the cell should, therefore, lead to the characteristics of life. Most of the students in the field of bacteria and viruses are not inclined to believe that what is true for a

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simple bacillus is probably true for larger organisms including man.

Primitive earth : On the primitive earth, life must have had its origin in the spontaneous synthesis of complicated molecules at the expense of smaller molecules. Under an environment where the temperature should have been few million degrees centigrade and every atom in a very highly excited state, it is not surprising to obtain all types of complicated molecules such as proteins, nucleic acids, phospholipids, polysaccharides, etc., which form the essential constituents of the present day living cell. Once these molecules are formed, it can be expected for some of them at least, that they may have formed aggregates exhibiting properties of life, i.e., a cell like structure. Before we discuss the implication of such ideas and sequence of events which provide a logical explanation to the origin of life, it would be important to describe the properties of a living system. A living system is an aggregation of molecules which has the capability to :

(i) Transfer and transform energy in a directed way,

(ii) Self-multiplication, i.e. transformation and communication of genetic information, and

(iii) Adapt itself to the changed environment (may be only a small degree of adaptation).

The question arises, at this stage, whether virus is living. The answer to this question is not simple because viruses present a border line case. Viruses are nucleoproteins. They breed correctly and have their heredity, multiply themselves, can synthesise their proteins but they do so only within suitable living cells. They cannot multiply in the absence of suitable living cells. They are unable to generate their own energy needed for self-replication. They are obligatory parasites of cells and take over enzyme systems of the infected cells in order to meet their requirement of energy. The virus is a living body only within the living cells and not outside. The question at hand is not the distinction between living and non-living but the formation of biologically active compound from a non-biological system and environment.

Formation of molecular compounds on the primitive earth : At present there seems agreement that primitive earth was originally surrounded by an atmosphere which comprised primarily of reducing material, i.e. atoms of hydrogen, oxygen, carbon and nitrogen which were in full reduced states and the atmosphere was dominant with respect to hydrogen. The reduced states of these primitive atoms are considered to have supplied the starting material for the formation of complex molecules. Table I shows the expected complex formation.

TABLE 1

Complex molecules from the primitive earth

Excited atom	*Molecule*	*Polymer*
Hydrogen	.. Acid	Lipids
Carbon	.. Sugar	Cellulose, starch etc.
Oxygen	.. Base	Nucelic acid
Nitrogen	.. Amino-acids	Protein

The energy needed for such transformation came from : (i) U.V. from the sun, (ii) cosmic radiations, (iii) radioactive material, and (iv) electric discharges.

In Table 2 the expected primitive molecules are given :

TABLE 2

The primitive molecules

H_2O	Co_2	CH_4	H_2	NH_3
HCN	HCOOH	HCHO	—CHO CH_2OH	
CH OOH	OOH CH_2 CH_2 COOH		NH_2-CH_2-COOH, other amino acids.	

All these compounds have been obtained in laboratory using conditions very similar to those expected on the primitive earth. This stage is a chemical stage of evolution and should have started sometime 2.5 billion years ago. The whole process in the chemical stage of evolution should have been at random and large number of molecules be formed. The next step within the chemical stage of evolution is the polymerization of small molecules as to produce complicated molecules such as polysaccharides, proteins and nucleic acids.

Let us consider the formation of nucleic acid in the non-biological system. A nucleic acid is a polynucleotide with molecular weight of the order of 10×10^6. The DNA molecules is one of the important compound related to the life. The backbone of DNA molecule is shown in Fig. 1. The basic unit of nucleotide thus contains a base, sugar (pentose) and a phosphate group. It is interesting to note that Palm and Calvin (1962) were able to produce HCN by irradiating the C^{14} labelled methane with electron radiation. When this compound in dilute aqueous solution was irradiated with electron radiation adenine (a pentamer of HCN) was formed. Ponnamperuma *et al.* (1963) were able to demonstrate that if aqueous solution of adenine, sugar and pyrophosphate is irradiated with U.V. the adenylic acid and ATP (Fig. 1) are obtained. This observation is significant from the point of view that not only can basic units of DNA be generated in the non-biological process but ATP, a high energy compound which is readily utilizable form of energy in all biological living systems, can also be formed in an abiogenic manner.

A more convincing experiment was performed by Gerhard Schramn (1963) at the Max Plank Institute for virus research. He prepared a mixture of simple purine and pyrimidine bases, sugar (2-deoxyribose), phosphorus compounds and mineral salt. He exposed this mixture to heat, pressure and electric discharge similar to those expected on the early earth. One of the resultant products was nucleic acid (DNA) with an almost identical structure of Watson and Cricks model of DNA. Though it was not a biological DNA yet it was a direct experimental proof that DNA in which the hereditary information of the cell lies, can be produced under non-biological conditions. If we consider that a large number of DNA molecules were produced on early earth by

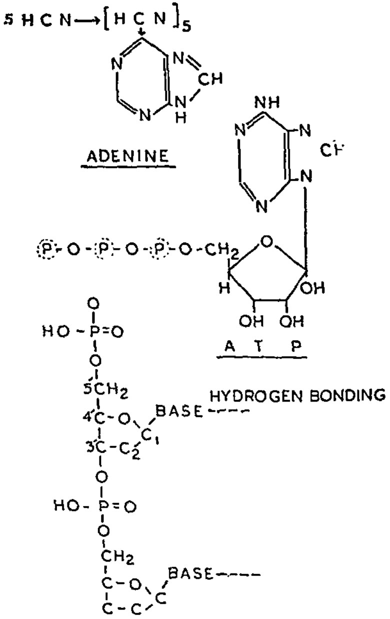

Fig. 1 : ATP & DNA BACKBONE

at random combinations of adenine, guanine, cytosine and thymine bases, it can then be expected that some of the so-produced DNA molecules may have all the properties of a gene, i.e. capacity of self-replication as the DNA of present day cell has. It is reported that such a gene probably appeared about 2.5 billion years ago.

Effect of environment of active DNA molecules, mutations in genes and formation of virus : We know today that gene mutation occurs and the rate of mutation is increased by high energy radiations such as gamma rays and X-rays. In the early days of evolution the earth was bombarded with intense radiations from the sun and also perhaps from the radio-active isotopes. Water is a good absorber of radiations, otherwise under such intense bombardment of radiations—life could not have existed. The genes whether single or in aggregates floating near the surface of the ocean must have undergone a rapid mutation. As a result of that and in the course of time, a large number of different genes should have been produced. At this stage, one could think of natural selection of genes, that is to say some of the genes might have survived while the others destroyed or inactivated. Some of the surviving gene aggregates should have had the ability to function like active genes. Many authors, todate, think that the virus is the simplest structure which shows the properties of life (though viruses behave like living systems only within the living cells). If such an idea is taken to be correct then we can conclude as follows :

1. Some gene aggregates should have been able to direct the synthesis of proteins from amino-acids present in their surroundings or the protein already present (synthesised by polymerisation of amino-acids in the presence of dehydrating agents) must have combined with nucleic acid to form a protein coat around the genes. This coat works as a protective layer for genes. This nucleoprotein (present day virus) should have been the form of life.
2. The water in the primitive ocean must have been very similar in its content to that found in the fluids of the living cell known today.
3. The cell, if there was any, must have been very different from the present day cell which contains a highly organized internal structure.

Formation of peptide bonds in non-biological atmosphere : Besides water, minerals and sugars, the other essential structural elements of the living cell are :

(i) Proteins
(ii) Nucleic acids and
(iii) Lipids

L-amine acids are the building blocks of proteins in biological systems. Protein is a large molecule. An average protein contains about 200 amino-acids, residues of 20 different types of amino-acids. The protein molecule after its synthesis assumes a specific shape which is maintained through secondary (hydrogen bonding,—helix) and tertiary structure (like disulphide linkage). It is known to some extent that every structure of the protein contributes to its biological activity. These are even more important in case of enzymes. It should, however, be pointed out that secondary, tertiary or quartenary structures follow the primary structure of the protein.

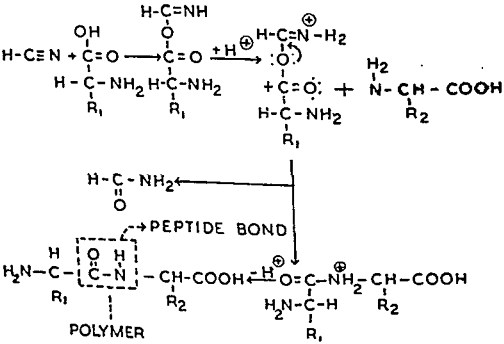

Fig. 2: FORMATION OF POLYPEPTIDE CHAINS BY NON-BIOLOGICAL METHODS

In the non-biological system, the polypeptides were obtained by Lowe *et al.* (1963). He used solutions of

amino-acids in HCN and heated them. In addition to ademine, polypeptide was also formed. One proposed mechanism by Calvin is given in Fig. 2.

The formation of protein molecules in the non-biological medium is again a random process. It is, therefore, not unreasonable to think that when a large number protein molecules are formed most of them, if not all, should differ in the primary structure i.e. in the amino-acid sequence and total number of amino-acid residues. It is also possible that at least some of the protein molecules may have the properties of the enzymes. In this way, it is easy to extend a logical explanation for the start of biological function from the products obtained from a non-biological system.

It would not be out of place to mention that an Indian team of Scientists viz. Dr. O. N. Perti of Nainital and Dr. K. Bahadur of Allahabad have claimed that peptide bonds cell like structures can be produced if the aqueous solution of amino-acids, sugar, phosphorus compounds and minerals is subjected to ultraviolet or visible radiations for sufficiently long time. They identified products by paper chromatography. Their work has been appreciated in the scientific circles even outside the country and has opened a new challenging field for research.

Can we mix the organic constituents and create living cells ? It is not possible at present but the progress that has been made in this direction points that within a very short period of time this will be possible. Today we are in a position to induce the synthesis of certain enzymes in living systems which are not possible otherwise. The knowledge of the genetic code, biosynthesis of proteins under genetic control, and advancement on the structure of sub-cellular particles of the cell has provided a guide-line in this direction.

NOBEL PRIZE WINNERS WHO HAVE CONTRIBUTED TO THE FIELD OF CELL BIOCHEMISTRY

Year	*Nobel recipient*	*Contribution*
1902	E. Fischer	Structural analysis of sugars and purines. Provided basis for carbohydrate chemistry.

Year	Nobel recipient	Contribution
1903	S. A. Arrhenius	Theory of ionization in electrolytes, contributed to understanding of chemical reaction and is of vital importance in the acid-base balance in the living cell.
1906	C. Golgi and Ramon, Y. Cajal	Structure of nerve tissue. Described the internal structure of the living cell in great details.
1907	E. Buchner	Discovered fermentation by means of zymase; occurs without whole cell. Provided new concept to enzymes.
1910	A. Kossel	Chemistry of cell. For the first time opened a field for research in which cell was used.
1920	W. Nernst	Studies on chlorophyll and chloroplast pigments. Heat changes during chemical reactions. Electropotentials on membranes.
1921	F. Soddy	Gave way to isotopic technique which revolutionised the living science and helped in understanding a large number of metabolic and physiological reactions.
1922	A. V. Hill and O. Meyerhof	Basic work on the metabolism of cells. Correlated oxygen consumption and production of lactic acid in muscle.
1923	F. G. Banting and J. J. R. Macleod	Discovery of insulin. Showed the way for the determination of protein structure.
1926	T. Svedburg	Worked on dispersion systems. Molecular weight determinations by ultra-centrifugation.
1928	A. Windaus	Showed a relationship between vitamins and sterols.
1929	A. Harden and H. Von Eulerchelpin	Fermentation and enzymes. Studies on the pathway of carbohydrate metabolism.
1930	H. Fischer	Worked on prophyrins. Established a relationship between heme and chlorophyll.

Year	Nobel recipient	Contribution
1931	O. Warbury	Studies the enzymes of the respiratory system. Respiration studies.
1932	C. Sherrington and E. D. Adrian	Function of neuron. Described the functional aspect of single cell.
1933	T. H. Moryan	Chromosomes as hereditary units.
1936	H. H. Dale and O. Loawi	Chemical transmission of nerve impulses.
1937	W. N. Haworth	Carbohydrate chemistry. Three dimensional configuration of sugars.
1937	P. Karrer	Worked on the structure of vitamins and showed requirements of cells for them.
1937	A. Szent-Gyorgyi	Oxidation in tissues; discovered furmaric acid. This work opened an exciting area for research at cellular level.
1944	J. Erlanger and H. S. Gasser	Studied different functions of a single nerve fibre.
1946	J. B. Sumner	Crystallization of urease enzyme. First to crystallize enzyme protein.
1946	J. H. Northrup and W. M. Stanley	Crystallization of viruses. Showed crystallized proteins still maintained the activity.
1946	H. J. Muller	Mutations with X-rays. Opened a new field of research in genetics.
1947	C. F. Cori and G. Cori	Action of insulin on sugar metabolism showed that external factors affect the cellular metabolism.
1953	F. Zernike	Phase-contrast microscope.
1953	F. Lipmunn and H. A. Krebs	Tricarboxylic acid cycle (Kreb cycle) and importance of phosphates.
1954	L. C. Pauling	Protein structure. Importance of secondary and tertiary structures in the function of proteins.
1955	A-du Wigneaud	Synthesis of a biologically active *protein—a hormone.*
1958	F. Sanger	Determined the sequence of amino-acids in insulin. Gave a precise structure of proteins.
1958	G. W. Beadle, E. L. Tatum and J. Lederberg	Worked on cytogenetics and bio-chemical genetics.

Year	Nobel recipient	Contribution
1959	S. Ochoa and A. Kornberg	Synthesis of nucleic acids. Gave impetus to molecular genetics.
1961	M. Calvin	Work in photosynthesis. Gave the pathway of fixation of carbon in photosynthesis.
1962	M. F. Perutz and J. C. Kendrew	Structure of globular proteins. An important contribution in the field of protein and enzyme chemistry. It helped understand the relationship between molecular structures and function.
1962	J. Watson, F. Crick and M. Wilkins	Gave double helix—Structure for DNA. Which revolutionized the life sciences.
1963	A. L. Hodgkin, A. F. Huxley and J. C. Eecles	Nerve impulses and synapses, structure-function at subcellular level.
1964	C. Block and F. Lynen	Cholesterol and fatty-acid metabolism. Elucidation of specific metabolic pathways.
1965	A. Lwoff, J. Monad and F. Jacob	Studies on control of bacterial enzyme synthesis. Gave the mechanism of the induced enzyme biosynthesis.
1966	Peyton Rous and Charles B. Huggins	Cancer is caused by virus in animals (Rous). Discovered hormonal treatment for prostate cancer in men and breast cancer in women (Huggins).

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Some Problems in the Development and Use of New Pesticides

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The use of pesticides as a measure of increased agricultural production depends on their efficiency and safety which are directly related to the behaviour of the many different types of organisms in the presence of organic compounds. The organisms may change the chemical nature of the compounds used as insecticide or metabolize them. Most of the compounds are detoxified and excreted without causing any hazard, whereas others are rendered biochemically inert and excreted without metabolism. It is, therefore very important to investigate the mechanism of biotransformation and detoxification which includes oxidation, reduction, hydrolysis and other related processes.

Serious hazards are involved in the use of most of the pesticides when their excretion or metabolism by plants and animals occurs very slowly. For example, DDT (pp-dichlorodiphenyl trichloroethane) accumulates in the fat system over prolonged periods of exposure. During a recent survey, some of the people in Delhi have been found to have about 300 ppm. of DDT in their fat. The animals exposed to DDT pass out this compound as such into the milk at relatively higher levels which may be lethal to the young. It is, therefore, possible that DDT applied to the plant or soil may result in a deleterious build up which then casues serious hazards to many forms of animal life.

Another serious example is that of TETRAM (O-O-diethyl) S-(B-diethyl amino) ethyl phosphorothiolate hydrogen oxalate which is not metabolized by the plants. This

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fungicide was some time used for the control of Dutch elm fungus disease. The leaves of the trees which received the application of TETRAM were found to contain as much as 4000 ppm. of the insecticide even a few months after the leaves had fallen down from the tree. The experimental rats which were fed on these leaves died immediately. The earthworms which came in contact with the leaves also died. Cholinesterase activity was affected even by the smoke from the burning of leaves.

A pesticide may be metabolized through a number of pathways.

$$\text{Pesticide} \begin{array}{l} \nearrow \text{Met. A} \rightarrow \text{Met. B} \\ \searrow \text{Met. C} \rightarrow \text{Met. D} \end{array}$$

Careful chemical analysis can reveal the nature of metabolites. Also analysis at various times might show the persistence of metabolite B or D and thus the metabolites A & C may be transitory intermediates. The compound A may also be toxic and may persist longer than Met. B which may be nontoxic. If A is not easily detectable then it would be a hazard.

Long term feeding of these compounds to dogs and rats should be done to solve this problem. If the pesticides are readily metabolized by dogs and rats, then *the toxicology of the metabolites would be partially evaluated* in the feeding study. Here in all cases pesticides have been metabolized in plants and animals through the same pathways, differing only in the rate of reactions. Cases may also arise where animals metabolize the compound through the paths A to B and the plants do it from C to D. This would cause errors in the feeding studies. In such cases it is necessary to evaluate the toxicology of C and D independently. The approach, therefore, would be to synthesize C and D and then studies in the toxicology of these compounds should be conducted.

The metabolites of a pesticide may differ from their precursor in localization, type and side of pharmacological action. A pesticide may accumulate in the fat while a metabolite may be concentrated in the brain, liver or somes where

else. A slight chemical change caused by its metabolism may change the localization or type of biological activity.

Certain difficulties arise when a pesticide reacts with some constituent of a normal body. There may be a physical binding of the pesticide to the cell constituent so that its extraction in the free state for residue analysis may be difficult. They may react with certain proteins, some nucleotide bases or even with selected amino acids or other simple molecules. This may or may not alter the biological activity of these proteins or other normal metabolites in the bodv. It is desirable, therefore, to evaluate the biological activity of these materials within the body. The pesticides or their metabolites may disappear but the biochemical disturbances and hazards might persist. Highly reactive compounds such as halogenated, acylated and alkylated compounds are the best examples. A fragment from a metabolite may persist following its binding and cause difficulty in the interpretation of residue and toxicity data.

To evaluate a hazard from a pesticide, we should know how it acts biochemically within the body. The experiments should be reduced to in vitro studies attempting to pinpoint the site of disturbance at an enzymatic level. If only B is active out of A & B, only B should be used for invitor enzyme inhibition studies. But without information on the formation and nature of B, studies on the mode of action are impossible.

Structure-activity studies to find new pesticides are laborious and expensive. Two analogues may result from the ability of one to form an active metabolite whereas a modified group in the other may rule out the formation of this metabolite.

One factor contributing to the selective toxicity of a pesticide is the way it is metabolized in different organisms. This may involve the metabolic pathways which may be different for different organisms but, more frequently, it is the rate difference between species for the same pathways which may still contribute to a high degree of selectivity.

Metabolism of pesticides is one of the prime factors involved in the potentiation and synergism of the activity of

these compounds. The activity of a pesticide is increased on mixing it with a synergist or potentiator. Many compounds containing methylenedioxyphenyl radical synergist increase the activity of pyrethrins. Potentiation means greater than additive toxicity of certain organophosphate mixtures. If the pesticide changes to an inactive metabolite B, the synergist or potentiator may block its conversion to B. We must know the chemical nature of the conversion of the pesticide to B in order to develop synergists.

Resistance poses a major problem with pesticides. Field resistance has been found in tick and mite species. The selection of organisms by repeated exposure of the population to high concentration of the pesticide may result in a strain which rapidly metabolizes the pesticide. Suppose a metabolite A is toxic. The selected strain may result from more rapid conversion of metabolite A to B or more rapid conversion to non-toxic C or D by the alternate route. This resistance may help us in the development of synergists or anti-resistant compounds.

Most of the problems resulting from the metabolism of pesticides in an animal body to form more toxic metabolites, result from a special mechanism in the body that deals with foreign compounds. This mechanism is localized in the liver microsomes containing enzymes which seem to metabolize foreign compounds but not their natural compounds. The microsomes are subcellular and submicroscopic but can be obtained as a centrifugal fraction. They are comparable to endoplasmic reticulum in the intact cell. A cofactor, usually the reduced triphosphopyridine nucleotide, is required if the microsomes are to act oxidatively. The cofactor is oxidized on reaction in the microsomes with suitable substrates (pesticides) in the presence of air. The microsomal enzymes utilize molecular oxygen from air and hydrogen from the cofactor to form a reactive hydroxyl derivative. The OH group catalyses N-dealkylation, deamination, aromatic hydroxylation, ether cleavage and reduction of nitro group, the splitting of azolinks, the oxidation of organic sulphur and alkyl chain oxidation. The properties of microsomal enzymes may vary with the species, sex, age and even the diet of an animal.

Examples : DDT (dichloro-diphenyl trichloroethane)

Animal fat or milk will contain both DDT and DDE. Milk can also be examined for DDT and DDE. Resistant houseflies to DDT contain a high level of enzyme DDT dehydro chlorinase which changes DDT to nontoxic DDE. Some compounds which are not attacked by DDT dehydrochlorinase are toxic to resistant houseflies.

Epoxidation : The epoxidation of cyclopetadiene group of insecticides to form toxic derivative is important, because these epoxides may escape detection by analytical procedure for the parent compound.

Aldrin	Dieldrin
Isodrin	Endrin
Heptachlor	Heptachlor epoxide

They occur probably via the liver microsome system. Expoxides may be further degraded in the body to give both the toxic and nontoxic compounds. The epoxides are as toxic as their precursors and may persist longer.

Parathion : It is metabolized in different ways in different parts of the body. The critical reaction is the oxidation of the phosphorothionate group to the phosphate counterpart or para-oyon. This results from the action of the liver microsome system. Para-oxon is a much more potent phosphorylating agent for choline-esterase than parathion and so para-oxon is an effective toxicant. Generally, females are more susceptible than males. With parathion, there is more rapid oxidation to the oxygen analoge by the female. This activity can be changed by giving the female testosterone, etc.

When parathion is fed to a cow or other ruminating animal, NO_2 is reduced by the rumen microorganism to aminoparathion. This is very rapidly absorbed in the system and gets into the circulation. Both of them are secreted into the milk but fortunately they are less toxic. These amino derivatives are not formed in man where the metabolized product is pnitrophenol which passes out in the urine. Many insects have developed a high level of resistance to phosphates. Probably it is due to the activity of the ester which is hydrolysed and is detoxified very rapidly.

Systox (O, O-diethyl-S-2(ethyl thio) phosphorothiolate) is an example. This is systemic and is applied to seed or soil. The thioether group is oxidized first to sulphoxide and then to sulphone. In mammals, these are carried out by the liver microsomes. The systemic ones may disappear rapidly in a plant but may change into toxic oxidation products. One way of analysis is the oxidation by perbenzoic aid to form sulphone and then evaluating it by its antichlone-esterase activity. Another procedure is separation by chromatography and determination of total phosphorus.

Non-enzymatic reactions with organophosphates : Three types of reactions are possible :

1. Phosphorothionate sulphur can isomerise to an S-alkyl derivative, and in some plants it occurs rapidly. This is equally toxic.
2. Some of the thioether compounds are susceptible to self-alkylation. The alkyl group or the intermediate cyclic sulphonium ion serves to alkylate the thiother group to yield extremely toxic derivatives; but fortunately they are unstable.
3. Some O, O-dialkyl phosphorothionates may be hydrolysed to phosphaorthonic ions that attack the original molecules and give more toxic compounds but these reactions have not been found to occur in vivo.

Malathion : (O, O-dimethyl S-(1,2 dicabethoxyethyl) phosphorodithionate) is excellent but is rapidly metabolized and therefore, it creates problems. The effective toxicant, the oxygen analogemalaoxon is formed by the liver microsomal oxidation system. Detoxification results from hydrolysis at each ester site to form 13 theoretical metabolites most of which have been isolated. Carboxyester group is hydrolysed forming nontoxic compounds. Use of synergists may block this process of hydrolysis and increase the toxicity. The resistance by flies and mosquitoes appears to result from this hydrolysis. A slight modification of malathion structure results in loss of toxicity. This involves changing of carboethoxy to carbomethoxy which is probably hydrolysed in the insects by an enzyme different from that needed to hydrolyse carboethoxy. This pesticide has a high insect toxicity and low mammalian activity because it

is hydrolysed rapidly in the liver. The combined toxicology of the chemicals mixed together should also be evaluated since its mammalian toxicity may be increased.

Carbamate (*Sevin*): I-naphthyl N-methyl carbamate is called sevin. The detoxification of such compounds in the mammalian and insect bodies appears to result from hydroxylation of either the cyclic structure or oxidation of a methyl group which is carried out in the microsomal oxidation systems. In these cases, several oxidative metabolites have appeared in insects, plants and mammals. Work should be done to evaluate these metabolites.

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Chapter V

Strategy of Research in Agricultural Universities

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Introduction : Agriculture in India has been a way of life, a family enterprise. For ages, traditions have been built around agricultural practices and have been transmitted from father to son. Only in the recent past has a significant attempt been made to understand agriculture as a scientific enterprise, as a business proposition. The fact that agricultural development can take place only through research has been known since long. During the latter half of the last century, several famine commissions were instituted to study the problem of famine. The Famine Commission of 1901 stated, "The steady application to agricultural problems *of research is the crying necessity of the times*". The first Agricultural College was started in 1903. The Royal Commission to study agricultural problems appointed in 1926 gave its report in 1928. In their report, they stated, "The basis of all agricultural progress is experiment. However efficient the organisation built up for administration and propaganda, it is merely a house built on sand unless it is based on solid foundations provided by research. Inspite of the marked progress which has been *made in many directions during the last quarter of a century,* it is hardly an exaggeration to say that agricultural research in this country is still in its infancy." The Famine Commission proposed the constitution of an Imperial Council of Agricultural Research. This was the beginning of the Indian Council of Agricultural Research we know today.

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The Indian Council of Agricultural Research (ICAR) and Agricultural Research in the States : The ICAR has been essentially an Advisory Body. The main function of agricultural research has continued to be with the State Departments of Agriculture, Animal Husbandry and Veterinary Science. The ICAR, in many cases, is financed partly or wholly by research projects initiated by the State Departments. Agricultural research in the States of Indian Union has been executed through experimental stations located in different parts of the State and under the control of the Directorate of Agriculture. In certain States, the Agricultural Colleges had few of the research projects located on their campuses and in some cases agricultural colleges, have been given a greater role to play in directing agricultural research in the State. The Directorates of Agriculture, Animal Husbandry and Veterinary Sciences continued to have the responsibility of imparting instructions through the Colleges, carrying of research through the experimental stations and taking care of the development work through its development machinery. Since instruction is rather an easily defined activity, by and large, this was carried on by the Colleges fairly independently and satisfactorily. The Department was complex government machinery judging its performance in terms of targets tied up with development the quantity of fertilizers used, the quantity of seeds distributed etc. The agricultural research thus was not adequately cared for either by the highly technical staff attached to the College or the Department. The ICAR being essentially an Advisory Body could do nothing much except make a note after the end of the research project that things could have been better if this had been executed more carefully.

ICAR and Agricultural Universities : The joint Indo-American Team report submitted towards the end of 1955 made a clear case for integrating research and instruction in agricultural colleges. For instance they said, "Colleges exist not only to teach students, but also to preserve and particularly to increase knowledge. A part of the armamentarium of a college for preservation of knowledge is the development of an adequate library; equally, perhaps even more important is the expectation that any professor or teacher in a college should himself endeavour to add to the sum of human knowledge in his field of specialisation. The teacher who takes no interest in research or is so over-burdened with

teaching that he can do no research, is rarely an inspiration or a model for his students".

The Agricultural Universities which have come into existence since this report, have taken as their guiding principles, the integration of research, teaching and extension education. However, except for one Agricultural University, the full integration of research in the State with the Agricultural Universities has not taken place. In every State where an Agricultural University has come into existence, the University must become the centre of research activity. This is very important from the point of view of maximum benefit to the creation of a team of agricultural workers who would be trained with an applied bias, at the same time with a strong scientific base. In addition, it has a very significant practical advantage. Usually the cream of the professional men are found in Universities. They are usually free from petty routine matters which are a plague in our governmental organisations. When such highly talented people get an opportunity to face problems of fundamental and applied nature in Agriculture, the result is the creation of new strains of crops and techniques for increasing agricultural production. This is in ample evidence by the results produced by the Punjab Agricultural University in its short span of life, and Central Research Institutions like Indian Agricultural Research Institute, National Dairy Research Institute etc.

In view of the above, the ICAR must direct all agricultural research activities in the country either through its own Institutions or through agricultural universities, wherever these Universities exist. In those States where Agricultural Universities do not exist, the ICAR should bring into participation the existing agricultural colleges to make them more research biased and in the course of time, these colleges can grow to the Status of Agricultural Universities.

In the Advisory Bodies when scrutinising technically the research projects or in guiding research policy, the ICAR must seek the participation of Specialists located in Agricultural Universities and Central Research Institutions.

The ICAR should act as a coordinating agency for agricultural universities in helping them to have a common sound

basis of agricultural education, without interfering too much in the details of instruction. The need for instituting special programmes of instruction, or splitting existing programmes, could be discussed and advice rendered without stifling the initiative of agricultural universities to forge ahead on programmes which appear too advanced for the orthodox mind but which may have a future 10-20 years from now.

The Scientists of Agricultural Universities may be used considerably by ICAR in the coordinated projects. This will bring in automatically a certain amount of integration of research in Central Institutions and Agricultural Universities.

Research with a Purpose in the Under Developed Countries

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All research worth the name has a purpose, even development of Hydrogen and Atom Bombs ! I presume, I am *required to speak of research which is connected with the* survival of human race, rather than its destruction, namely agricultural research which is the concern of this forum. The purpose could be variously defined and visualized. The often quoted phrase "how to grow two blades of grass where one grew before" has inspired research workers in the agricultural field for more than a century. No doubt, more than two blades have grown in place of one since this was said yet the addition of hungry mouths at the same time has more than wiped out the gain. The present position is that 2/3rd of the world population suffers from malnutrition and vast numbers are virtually starving. The population of the world by the close of this century, i.e. within the life time of many of us, is expected to double itself. If no break-through occurs in accelerating food production and retarding the rate of growth of population, the magnitude of malnutrition and *hunger in the years ahead shall be appalling.* No doubt, the food problem has always existed in the history of mankind and hunger and malnutrition have been part of the life of the people in some parts of this globe; yet the magnitude of this problem has never been so great as at present. This is, despite the fact, that never in the history of mankind, was it technologically feasible to produce enough and to mitigate hunger and famine. The purpose of research in the agricultural field in under-developed countries, therefore, is to devise ways and means of technological

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advances of a practical nature which would make it possible to produce enough food and fibre at least for the minimum requirements for the present and the projected population of this part of the world. It has been estimated that if the present rate of population increase continues, by the end of this century, the under-developed countries to be self-sufficient, will have to produce food equivalent to the total present production of the rest of the world. The task seems to be stupendous but by no means impossible.

Most of the under-developed countries of the world achieved political freedom in recent years; this freedom loses much of its significance if it does not bestow freedom from hunger, want and misery. Since the dawn of civilization, it has been realised that a hungry people will not endure reason, they will not listen to justice and they will not bend to any prayers for mercy. The difference between right and wrong vanishes when the stomach is empty. These areas of the world are, thus, not at all enjoying freedom in the true sense of the world and are danger spots for world peace. The purpose of agricultural research as an instrument of increasing food production in these areas should, thus be viewed as a struggle for freedom for the peoples of those areas and as a mission for world peace.

Let us now examine some of the problems in the field of research in the under-developed countries, ours being one of them. I shall only touch at some of the salient points.

Resources and priorities : The under-developed countries, by the very nature of their economic situation, can spend very paltry sums on research activities; whereas countries like the United States and the USSR spend* 1.8 per cent of their total national income on agricultural research; in India, this amounts to 0.06 per cent. In matter of per capita expenditure, it amounts to Rs. 154 and Rs. 110 respectively in the United States and the USSR, compared to 15 paise in India. The resource position, being what it is, it becomes imperative that research should be conducted with a clear objective of obtaining results of immediate economic importance. The question of relative emphasis on applied and basic research in the Agricultural Universities of India was

*Source : Science & Agriculture : 23 : 398 (1958).

discussed by Kanwar (1965). He tried to classify research into categories depending upon the prospects of immediate practical usefulness, and reorganizing different levels of research in relation to prospects of success and the anticipated difficulties in execution. According to him, the simplext level would be the variety, fertilizer, rate and date of seeding trials etc. designed primarily to exploit known principles and to answer the farmers' immediate needs.

At the second level would be the observations or experiments designed to determine as to why certain of these treatments were better than others. This type of research could be carried out in conjunction with the first.

At the third level would be research designed to determine the basic physiological or biochemical causes for such phenomenon as resistance to pests and diseases, the mode of inheritance of plant and animal characters, life histories of pathogens, interrelation of hormones, amino acids, trace elements etc., in the nutrition of plants and animals.

At the fourth level, would be the research designed to provide better understanding of such phenomenon as photosynthesis, photoperiodism nature of genes and the relation of molecular configuration to the toxicity of pesticides, etc.

At the final level might be research which is not directed or restricted in any way except that it might be related to some phase of animal or plant growth. Even this restriction could be disregarded in case of individuals whose aptitude and performance prove their ability to conduct productive research in this category.

There is no doubt that there is need to carry out research at all these levels provided there are enough resources available in men and material. A question might be raised here about the fundamental and applied research. On this issue, I may quote Trullinger (1951) that all research is basic or else it is not true research. The superficial experiment that does not result in the establishment of permanent scientifically sound facts would, in the long run, be a costly proposition. At the present time, most of the under-developed countries may not be able to finance, on a significant scale, research of the higher categories mentioned before. Their

immediate need is to exploit the known principles in various disciplines for the solution of problems which may yield quick economic returns.

It is very important, however, that whatever research work is contemplated should be planned and executed on sound scientific principles. The persons who are entrusted with administering agricultural research should clearly understand the problems of agricultural production and should be able to fix priorities in relation to resources. The workers who are assigned these problems should have very sound training in their respective disciplines and should be familiar with the latest scientific principles and techniques. They should remain abreast of the growing knowledge in the world in their respective fields. Although in the past in areas like plant breeding, some notable achievements were made by workers who practised it as an art and as recently as 1955, Harland stated "Plant Breeding has not yet ceased to be an art, and the plant breeder who loves his material and lives with it night and day, still plays a most important part. Long may he live, crossing the best with the best and hoping for the best...." Although, the art part in plant breeding is a matter of loving the material and living with it will continue to be important, yet the time of "crossing the best with the best and hoping for the best" seems to be over. The recent work in this University has proved beyond doubt that sound knowledge of the fundamental principles on the part of plant breeder pays dividends.

In the matter of resources and priorities, my view is that in such parts of the world where resources are meagre for undertaking research of the higher categories mentioned before (call it basic research if that appeals to you better) on a significant scale, persons recruited for solving the problems must have had training in institutions which are engaged in such research. Steps must be taken that they remain in touch with such institutions by studying the latest literature published by them and also by occasional visits. The highest priority should be given to attract brilliant young men to this field and given training opportunities as I have just mentioned. The investment in such persons by these nations will, no doubt, pay handsome dividends. These persons could, in due course, build these institutions where research could be extended into higher spheres.

Research collaboration : The world today has become very small. With improvement in communications, it is possible to establish contacts with the most remote corners of the globe. It is a matter of satisfaction that this is gradually being recognised in the field of agricultural research. A very encouraging feature of agricultural research in recent years has been the establishment of institutions in under-developed parts of the world with collaboration and assistance of the advanced countries. The International Rice Research Institute, Philippines and the Wheat Improvement Project in Mexico are outstanding examples of International collaboration in research. These institutions are not only becoming great sources of germplasm for these crops but also a great pool of scientific talent from all parts of the world. Along with hybridization of plant material, cross fertilization of scientific thought is bound to take place. Both of these aspects are full of hope and promise.

Collaboration in these terms has cut across political boundaries and has helped in obtaining results which individual countries probably could not achieve. There is immediate need for these types of institutions for the important food and fibre crops like millets, oilseeds, pulses, sugarcane and cotton. Although this type of approach would be more fruitful in the field of plant breeding, this pattern may be developed with great advantage for solving problems in other disciplines also. There appears to be great scope in this direction in the field of animal breeding, an area very much neglected in the under-developed countries.

Research to replace draught animals with machine power : One aspect of agricultural research which has very often been overlooked in the under-developed countries is the mechanization of agriculture. A very considerable part of the agricultural produce of the world today is consumed for production of animal power. It is difficult to ascertain how large a part of the produce is actually used to maintain draught cattle but quite clearly it is very considerable. According to Cooper, Barter and Broctell as quoted by Osvals (1966), 30 per cent of the increase in foodstuffs supplies that occured between 1920-1942 in the U.S.A. was obtained from those areas which had become available owing to decrease in the number of draught animals. It has been estimated (Osvals, 1966) that if all draught animals could be replaced

by motor power, then the freed area could produce food for one milliard people (i.e. almost twice the present population of India).

Very little organized research on mechanization of agriculture has been undertaken in the under-developed countries of the world. In this state, there is a keen demand for the equipment to mechanize medium-sized and even small holdings. It is a matter of great satisfaction that this University has given a lead in this direction by establishing a College of Agricultural Engineering where research and development on farm machinery to suit our conditions is making headway. I hope that this part of our country will give a lead in the farm mechanization to the under-developed countries of the world. I am convinced in my mind that without mechanization and getting rid of surplus cattle, we cannot properly feed ourselves.

Research publications : The research in the under-developed countries has to be service-orientated and devoted for the solution of agricultural problems. The greatest incentive for the research work should be the satisfaction of having increased agricultural production and income of rural communities. It is important that results of economic importance are published and disseminated with speed with this end in view. In the past, the flow of publications from the research projects has not been satisfactory. There is great scope for improvement in this direction. It may, however, clearly be understood that the research publications should be a corollary to the basic goal of increasing agricultural production and not an end in themselves.

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New Concepts of Agricultural Research and Extension

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From pre-historic times, for many centuries, man continued to depend on food by gathering fruits and other edible parts from trees and plants and hunting wild animals for flesh. Then came a change in his thinking and he started growing plants and trees for his convenience around his primitive type of living abodes and used to harvest and gather food from these plantings. He also started domesticating animals—both for food and to use them for his conveniences such as riding, haulage and cultivating land, etc. This process continued for a long time and even today in certain remote pockets of the world, agriculture is still practised by certain tribes in a primitive manner, for example, in tropical Africa certain tribes do not settle on land to practise 'jhooming' and keep on shifting the cultivation of land to new forest patches, by burning and cleaning them. Similarly, certain tribes in other parts of the world are still leading nomadic life and feel themselves contended by rearing large number of cattle and they keep on moving from place to place in research of forage for their cattle.

Traditional agriculture : With passage of time the cultivator started making selection in plants, trees and animals and he also started perfecting various tools and implements to make his job more convenient. He also started learning from *experience* and started adopting certain practices of his neighbours for improvement which used to impress him. This process continued for long time and various agricultural practices were accepted by him almost as tradition and this

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Strategy in Agricultural Research*

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Present-day agriculture is vastly different from that of the past. It has reached a high degree of development in certain areas of the world. In the under-developed countries, however, there is still a wide gap between the actual and potential levels of agricultural production. The nature of the problems which require solution through research are greatly dependent on the stage of development of agriculture. The emphasis or strategy in agricultural research in advanced countries varies considerably from that of the under-developed countries.

It is estimated that nearly half of the world's total population of 3.1 billion is malnourished. The future can be even darker unless great strides are made in food production. By the year 2000, the population of the under-developed countries is expected to more than double. To feed the growing population and improve the diet modestly, food supplies have to be increased 306 per cent in the Far East, 207 per cent in the Mid-East, 239 per cent in Latin America and 159 per cent in Africa (according to United Nations). By contrast, food production in this areas as a whole increased by 54 per cent during the last 25 years. Per capita food production in these regions has actually been declining between one to two per cent a year since 1958-60 period.

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*Some of the material contained in this paper has been taken from the Report of the Second Workshop of the Agricultural Universities in India held in February, 1965 at Pb. Agril. Un., Ludhiana.

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In a developing country like India, where the population is outstripping the food resources, it is essential that agricultural research should be directed to the solution of problems of immediate importance. The research should aim at increasing production of food, milk and meat rapidly. In the Agricultural Universities, priority should be given to the development of research programmes that will aid the cultivators in producing more food. One of the reasons for success in American Universities has been the dedication of the research worker to enable the American farmers find solution to the problems confronting them. Under the existing food shortage conditions, the Agricultural Universities and the Agricultural Research Institutes have a heavy responsibility and can play a vital role in alleviating the grave problem of food shortage.

Broadly speaking, we should not at this moment dissipate our energies in the luxury of merely finding new knowledge which cannot support our needs. Many times the question has been raised regarding the relative importance of applied and basic research in agriculture. There is no clear cut definition of basic research, but according to general belief, basic research adds to our knowledge without any thought as to how knowledge may be used for the benefit of mankind. Whether or not we accept this definition we should accept the concept that research in Agricultural Universities should be generally directed towards the solution of problems of the cultivator. Probably a better terminology would be directed research that which is directed towards the solution of research problems and, undirected research that which is not directed to the soluiion of any specific problems. As long as the spectre of acute shortage faces our country, the agricultural universities should derive maximum satisfaction by contributing to the development of agriculture. In doing so, it is often necessary to conduct fundamental research in support of the practical research programmes. Sometimes, when a ceiling is reached in our efforts directed towards applied research, new methods and techniques have to be discovered. New methodology developed through basic research may in turn yield results of great practical significance. As the more common problems are solved and more complex ones arise, basic research has to be pursued to seek new information which can be applied to the solution of more complex problems. The major question is

whether research will serve a useful purpose or whether it will be carried out merely to satisfy the whims of the researchers.

About six decades ago, studies were initiated in U.S.A. to determine the effect of inbreeding in maize. This work was probably never planned to find a solution to any practical problems. The results of these investigations ultimately demonstrated manifestation of hybrid vigour in crosses between inbreds and thus led to the discovery of hybrid corn which was probably the most important single factor in revolutionising American agriculture. In our work with pearl millet at the Punjab Agricultural University, efforts were made several years ago to develop genetic stocks for linkage studies. During the course of this work, cytoplasmic male sterile lines were discovered which have provided a practical mechanism for the production of hybrid seed.

While this broad objective is useful in finding the direction, it may not be sufficient to determine the exact problem or special procedure to follow. There may be many problems and several approaches to each of them and a choice must be made between the problems and procedures which present themselves. For example, the broad objective may be to develop a better veriety of wheat; but the breeder must decide in what way he is going to make the variety better whether by breeding for higher yield, superior grain quality or resistance to a disease. Also, he must choose the parent material to be used and the breeding procedures to be employed. Consideration has to be given to the range of problems which require an answer and the relative gain that may be made from the choice of alternative problems. Other factors to be taken into account are the capabilities of the research workers, facilities, equipment and funds at their disposal, relative research cost in relation to the gain and the probability of success. The research worker should be fully aware of the practical problems by keeping very close contact with the cultivators. If the birth of an idea arises within the research worker, the work will be done with more dedication and precision than if the worker is merely asked to carry out a programme, suggested by someone else.

The research project should have a clear objective and plan of work. A review and constructive criticism of the

project by other scientists or scientific committees can be of great value. It is important that research is carried out with a sense of urgency in order to achieve the objective in the shortest possible time. Plant Breeding is long range discipline and requires patient research. In the past it used to take about 12 years to develop and release a new crop variety. In recent years fast and spectacular progress has been made by raising two or three crop generations in a year. Means have now been developed to accelerate the research work in this manner in case of several field crops. In the conduct of research, the complete elimination of red tape appears to be a very important factor for success. It has been generally found that most valuable and speedy results are obained if the research worker is least dependent on others. The motive in research should be to discover something new and find the solution to a problem and not merely write up bulky progress reports. Sometimes the research work carried out over a period of several years proves futile, if techniques employed or the material utilized are not satisfactory. In plant breeding, many times the non-availability of wide germplasm has been found to be an important factor in limiting the success of the programme. Without basic plant material and proper techniques, a crop scientist would be like a mechanic trying to build a modern atuomobile with crude tools of his trade.

More and more, research is becoming a team effort involving joint coordinated efforts of workers in several related disciplines. Efforts should be made to intensify research by a team of specialists working on different aspects of the same problem, so that the problem is tackled as a whole at one time. The cooperation amongst scientists working in the same discipline at different institutes leads to efficient research on account of exchange of ideas and material amongst them. Taking an example again from crop improvement research, the development of a superior crop variety will require joint and collaborative research by plant breeders, agronomists, entomologists, plant pathologists and biochemists if the objective is to develop a high-yielding good quality strain, possessing resistence to various diseases and pests. In the development of scientific agriculture many more scientists in different fields have to work closely together, as for example, agricultural engineers, soil scientists, agricultural economists and others.

The application of results of research on various problems requiring immediate solution will result in a shift from the relatively primitive to a more advanced and intensive pattern of agriculture. The utilization of modern methods of production will bring in its wake new problems to be tackled by scientists. It is imperative to plan in advance and to foresee the problems that will arise in future and limit production, well ahead of time, so that there may be the least possible lag between the problem and its solution.

The Impact of Scientific Research in Changing Agriculture

D. S. Athwal*
PH.D. (SYDNEY)

The beginning of the existence of man is the most significant single event in the history of the world. All other products of biologic evolution become relatively insignificant when compared with the violent changes man has caused during his short span of existence. Today man is the master of every form of life, but his own. He has destroyed or modified other forms of life to suit his needs. The invention of agriculture signalled the end of a biologic system based primarily upon physical competition and the survival of the fittest. When man learned to grow plants and to domesticate animals, society became more organised. This doomed other forms of life to secondary roles due to the restrictions imposed by man. Simultaneously, the stage was set for man to multiply himself. Until today he is to be found essentially everywhere. At one time, the increase in the number of people inhabiting this earth contributed to progress; while today the population appears to be more than our earth can support. The population of the world is at least doubling during each half century.

Man has been long concerned with expanding agricultural production. Malthus postulated in 1798 that human populations, if not checked by war or disaster, would increase until they suffer from starvation. He foresaw catastrophe and predicted that Britain would be in misery by the mid-nineteenth century. However, the prediction was not

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realised because he under-estimated man's ingenuity in increasing agricultural productivity. About the same time, the poeople in relatively advanced countries were ushering in the age of scientific agriculture which brought about tremendous increase in food supplies as a result of better methods of production and improved varieties of plants and breeds of livestock. The advent of the machine age had a profound effect not only on the efficiency of production but also on the efficiency of utilization of agricultural produce through better methods of preservation, storage and marketing.

Modern agricultural production is a triumph of the application of knowledge derived from research to problems of human nutrition and welfare. During the last three or four decades, agriculture has undergone a full scale revolution as a result of integrated application of many technologies to the total problems of crop and animal production. Advances in the engineering, chemical, physical and biological sciences have, in most highly developed countries of the world, promoted improvements in agricultural production in new orders of magnitude. Convential agriculture, as it exists today, is far different from the pattern practised in the past. Amongst the most spectacular developments have been the mechanical aids, chemical control of diseases and pests and techniques of soil and water management. When the science of genetics joins hands with other disciplines, the total effect becomes tremendous. The manipulation of genetic potentialities of crop plants and animals by hybridization has resulted in varieties of domestic plants and animals which, in terms of their usefulness to man, are more successful than anything ever encountered in nature. The single discovery of hybrid corn in U.S.A. doubled the yield potential of this crop. Hybrid corn is a far reaching development in applied biology and its significance in human affairs is manifold. It did much more than simply offer an opportunity to increase production of corn. In biological terms, it acted as a kind of catalyst that transformed the entire agricultural economy in America. The use of hybrids brought in their wake other improved agricultural practices and made the American farmer receptive to an entire complex of new and improved methods based on sicentific research.

There is a real potential for increasing food production in India. To achieve this objective, we have to make a clear

choice between scientific agriculture based on modern technology and primitive agriculture. The present average yields per acre are miserably low and are generally a fraction of those of the leading countries. The consistent increase in foodgrain production per unit area in developed countries indicates that even those countries have not reached a ceiling on yield levels. The horizons in developing countries for potential yields are far beyond what we believed until recently. New high-yielding crop varieties are capable of giving 5 to 10 times the present average yield with adequate application of fertilizers and irrigation and adoption of improved cultural practices and plant protection measures. The supply of new agricultural land is decreasing steadily and further advances will have to be made by increasing the yield per unit area by new production methods.

The superstructures of more productive agriculture are laid down through research. The most important areas of research which can help increasing food supplies pertain to the development of superior crop varieties, the use of optimum doses of fertilizers based on soil survey, soil testing and results of fertilizer trials, the formulation of effective plant protection measures for control of diseases and pests, the designing of improved agricultural implements for preparing good seedbed and securing good crop stands and finally the efficient handling of the crop at maturity. Research on soil and water management will lead to a most efficient use of our resources. The preservation of the food produced and its proper utilization based on scientific knowledge is another important aspect. Apart from foodgrains, the increase in the production of animal products through scientific feeding and management of poultry and cattle can make significant contribution in increasing food supplies.

In the rest of this discussion, I shall refer to some of the recent advances in the field of plant breeding to demonstrate the impact of scientific research on Indian agriculture. The last ten years have witnessed very rapid advances in plant breeding in our country, some of these can be classified as major breakthroughs. The development of dwarf varieties of wheat and rice and hybrids of sorghum, *bajra* and maize have resulted in dramatic increases in food production.

Efforts had been made for a long time to exploit the phenomenon of hybrid vigour for raising the yield potential of *bajra*. Unlike maize, however, the male and female flowers of *bajra* are borne on the same inflorescence which makes it impossible to emasculate the plants on a large scale for the production of hybrid seed. For a long time it was generally agreed that this crop is amenable to only limited improvement. The prospects of producing hybrid seed brightened with the discovery of cytoplasmic male sterility in *bajra* first in U.S.A. and then at Ludhiana. As the male sterile lines do not produce functional pollen these depend entirely for grain formation on pollen supplied from other plants capable of producing normal pollen. The discovery of cytoplasmic male sterility, therefore offered, a practical mechanism for the production of hybrid seed. The potential of the male sterile lines was quickly recognised and the breeding procedures were accordingly modified to develop hybrids for commercial cultivation. The research work was expedited by taking two to three crops each year. A large number of inbreds capable of restoring fertility of the male sterile lines were immediately developed. For the first time hybrids based on cytoplasmic male sterile lines were tested for yield in 1963. The yield trials were continued in 1964. On the basis of All-India Coordinated Trials laid out in all the important *bajra* growing states, the best hybrid was found to yield nearly twice as much as the previous improved varieties. This hybrid was named as Hybrid *Bajra* No. 1 and immediately released for general cultivation all over the country. *Bajra* which was going out of cultivation in the Punjab has now been taken up by farmers even in areas where it was not previously grown. In large demonstration plots in several *bajra* growing states, grain yields up to one ton per acre under rainfed conditions and about two tons per acre under irrigated conditions have been obtained on the cultivators' fields. The average yield per acre of *bajra* in the past has been less than 1/7th of a ton and with the open-pollinated varieties the farmers obtained a maximum yield of about one ton per acre under good conditions. In 1966, a record yield of 2.7 tons per acre was obtained from a demonstration plot of hybrid *bajra* in Haryana. These achievements have raised the vision of the farmer who is now convinced that *bajra* which was considered low yielding is capable of giving more than two tons of grain per acre.

Basic research material has been built up for securing further increases in the yield level of this crop. The plant type in future hybrids should necessarily be dwarf which will make it highly fertilizer responsive and bristling can be incorporated to give protection against birds. The availability of new seed parents marks the beginning of a new era in *bajra* breeding. Two cytoplasmic male sterile lines discovered at Ludhiana have been found to possess a different cytogene mechanism as compared with U.S. male sterile line. Many inbred lines which did not restore the fertility of U. S. male sterile line have been found to be capable of restoring fertility of Ludhiana male steriles. The recent work has resulted in the development of isogenic lines incorporating three different sterile cytoplasms, which offer amazing possibility in the development new hybrids.

Another impressive success in the field of food production during recent years is the introduction of Mexican wheats. Several improved varieties of wheat developed in the Punjab and other States had been released to the growers in the past. However, all of these were tall growing and the application of nitrogenous fertilizer frequently resulted in lodging with consequent reduction in yields. The response of these varieties was limited to 25 or 30 kg. of nitrogen per acre which produced a maximum yield of 1.5 tons per acre. A similar situation existed in Mexico when average yield per acre there was comparable with our present yields. In 15 years, from 1950-1965, Mexico became an exporter of 4,65,000 tons of wheat from an importer of 4,24,000 tons. The average yield per acre in Mexico has more than doubled. The most important single factor which led to this revolution, in wheat production in Mexico was the development and release of dwarf varieties capable of responding to high doses of fertilizer. A similar breakthrough in wheat production can be accomplished in India. And a beginning in this direction has been made with the cultivation of Mexican wheats in 1965-66. Large quantities of seed of two Mexican wheats Lerma Rojo 64 and Sonora 64 have been imported and distributed to the farmers to raise the level of production. Dwarf wheat strains even superior to these two varieties have been developed from a large number of progenies of crosses obtained from Mexico. Two such strains, amely PV-18 and Kalyan 227 have been released for cultivation in preference to the Mexican wheats by the Punjab Agricultural

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drooping leaves were essentially suitable for low levels of fertility. These varieties have no place in present day farming as their response is limited to 20 to 30 kg. N per acre. This weakness was removed by developing suitable strains from crosses between the tall growing *indica* types and exotic *japonica* types, the latter possessing short and stiff straw. Due to sterility in the inter-racial crosses, much headway could not be made in this direction. A major breakthrough in the development of fertilizer responsive paddy varieties came with the discovery of a simple inherited dwarfing character in the *indica* varieties in Taiwan. Taichung Native-I, an introduction from Taiwan, gave an excellent performance under Indian conditions. It is an *indica* type with short stature, compact form and uniform tillering. It yielded over 50 per cent more than the local variety. In demonstration plots in the Punjab, yields up to 3.5 tons per acre were obtained on the cultivators' fields. However, Taichung Native-I is susceptible to diseases. The introduction of a more promising dwarf variety, IR-8 bred at the International Rice Research Institute, Philippines has filled an important gap in rice production. With the crosses of these dwarf *indica* varieties with local varieties now under study, we are on the threshold of attaining a real good variety for increasing rice production.

The majority of farmers are illiterate and conservative and have been rather slow to adopt new agricultural practices in the past. Whereas the previous improved varieties gave them hope of marginal increase in yield, the new varieties have shown the way for dramatic increases in production. Today the farmers are prepared to pay more than ten rupees for one kilo of Hybrid *Bajra* or dwarf wheat Kalyan 227. The release of such high-yielding varieties has initiated a great psychological revolution in the minds of the farmers. They recognise the merits of superior seed as well as other research findings, and look upon the agricultural workers as their greatest benefactors and the Agricultural institutes as their temples of learning. Only a few years ago, the farmer did not believe that one acre of wheat could yield three tons of grain while today he is prepared to project that even five tons would be possible. He is ready to add higher doses of fertilizers than recommended with the ambition of securing the maximum yield. This change in the attitude of the farmer is the beginning of a chain of reactions which will

Basic and Applied Research

R. P. KAPIL*
PH.D. (LYON)

Man became conscious about enquiry into the natural and physical forces centuries ago, but it was rare until the early twentieth century that the common man demanded the utility of the enquiries for which public funds were being paid. Man's quest for new things and ideas and his desire to conquer the other world and disease brought in an idea of better standards of life, accompanied by industrial and agricultural revolutions. Such proposals as the classification of Lepidoptera of a region, mimicry of butterflies and grass lands of Terai, were not difficult to pass through. Enough evolution in thinking occured to the end of World War II when the cost of financing research projects increased enormously and had great impact on the common man's mind. Man began distinguishing between the importance of various research projects, and before providing funds, he would demand the practical use of each proposal. The Senate or Parliament or it scientific committees were his meeting ground and its was not uncommon that a long discussion on a single academic project which might have had an inherent utilitarian property in the distant future, was unconvincing to him. Some proposals were often ridiculed because they did not stipulate immediate practical utility. The scientists on the committees were in a dilemma and in order to find a solution of this un-ending sterile dialogue, some sort of classification of research projects became necessary. But while suggesting all that, he never perhaps thought that he would be fitting a square peg into a round hole.

This happened actually because there is no clear cut differentiation between basic and applied research.

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leading with increasing rapidity to applied research that has been of widespread benefit". Gross's categorisation seems more near to the "mission-related" idea of basic research of Waterman, in which the doer is not expected to provide an immediate practical solution of the problem, as normally asked for from an applied investigator, but has a purpose which may be purely speculative and the results may provide some method to tackle the applied aspect.

Saunder Mclane is of the opinion that distinction between applied and basic research is possibly a matter of time. Mathematics that was considered about 25 years back as the purest science, has not only proliferated deep into all other branches of science in revolutionizing the others, but has completely changed its own face and is today the only effective applied tool. Similar instances are not few. Existence of vitamins was known long back but their importance as co-enzymes, demonstrated by Monod through the nutritional studies on Escherischia Coll during the fifties, has opened new vistas of applied research and has created possibilities applicable in the not too distant future of correcting defective protein synthesis.

The analysis of ideas permit us to think of the complexity of the problems proposed in each discipline, the way and the conditions in which they were worked out and the results drawn make it difficult to put a clear border between the expressed concepts of "basic" and "applied" research. They are in fact the limbs of the same body and are functionally inseparable. Whatever controversy exists is mere ideological.

Birth of an idea : The story does not terminate here, because it is usually thought that the fundamental idea or research follows its application. This is not always correct. The illustrations discussed earlier show that two-way traffic is possible. For instance, DDT has been known as a chemical since 1879, but its insecticidal property was revealed in 1944 during World War II. An applied idea was first borne and it was not long before it was realized that insects were getting resistant to the chemical. Did this mean that the idea was dead ? It was not. It had in fact stimulated certain possibilities, the most promising being to understand the mechanism of resistance. This is now known to lie in the changed configuration of DDT. A small alteration in its

Meaning of applied and basic research : To science two functions were attached even during Sumerian and Greek civilizations. The first was to enable us to know things and second was to provide us means to do things. The Greeks were interested in the first, and it is said that interest in the second item emerged through superstition and some mystical powers, demonstrated now and then. The Arabs then tried to discover the philosophers' stone, elixir of life, and wished even to transform base metals into gold. Which one of the two concepts should be called "basic" ? Many attempts have, therefore, been made by the students of social, natural and political sciences to define and demarcate "basic and applied" research. Most definitions unfortunately are subjective and are not meaningful. But it is certain that basic research projects are motivated with qualities of their application. Stephen Toulmin defines basic research as "research whose direct relevance to the specific missions of the agency, cannot immediately be demonstrated, calling attention to a predictive judgement about the applicability of the work, rather than to the goal of the man pursuing it." Another dividing line between the two concepts is whether the research project produced new knowledge, new ideas or facts. If these ideas are accepted as having bearing on the terminology they suggest the intrinsic value of the proposal rather than the state of mind of the investigator.

The situation in which a person works or explains the value of the investigation is an important guiding factor. Howorth pointed out that a piece of investigation which may be an applied research for a University Scientist, striving to explore new facts is likely to be basic for a Research Engineer, who may like to utilize the results. Similarly, the soil Physicist and Bio-physicist do not embark on the Universals of Physical Sciences but only utilize the established laws applicable to the respective fields and at particular situations. The situation tells of their application because they (laws) do not provide insight into the fundamental nature of the matter but describe its arrangement. Paul M. Gross presented before the House Sub-Committee on Science, Research and Development of the Senate of United States of America concrete evidence of the value of basic research, based upon experiments with screw-worm flies sterilized by X-rays. He went on to emphasize gains to the livestock industry of Florida and added that "basic research has been

Long Range Practical Benefits of Basic Research

I. S. BHATIA*
PH.D. (J. HOPKINS)

Much has already been said on the subject on which I wish to speak to you this morning. The subject is a very vast one and I can at best try to quote a few examples to support my thesis. I have tried to choose most of the examples from the fields which have some direct or even remote connection with Agriculture.

Basic research has invariably been undertaken without any definite practical end in view. A large number of important discoveries in science have come about indirectly from purely academic pursuits. Farady's electromagnetic phenomenon which has bestowed immense benefits on mankind was discovered and pursued without any regard for its potential use. Only its important exceptions immediately come to the mind. Newton's work on optics arose out of an attempt to improve lenses. Edison, did much of his work with definitive objectives and succeeded admirably. As a by-product of the applied researches of both these scientists much information of basic nature was discovered.

I will now give a few examples to highlight the practical benefits which have accrued to mankind from basic research.

Synthetic fibres : Food, clothing and shelter are the three primary requirements of mankind, and from the dawn of civilization, man has continuously striven to improve the quality and availability of these basic necessities. Few other developments in recent years have affected the average

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molecule, changes its toxicity. The change in the chemical structure of the insecticide molecule offers new possibilities of synthesizing new materials. Here an application has given rise to the exploration of basic ideas which are likely to provide ways of sustained application for manufacture of new insecticides or potentiation of existing ones. The story of the concept of mutation and its application, however, runs in the reverse order. It may be recalled to mind that the origin of an idea, whether basic or applied is a matter of chance and is not guided by the rule-of-thumb.

In the final analysis of the foregoing discussion, it may be concluded that all that has been talked about at various occasions to define "applied" and "basic" research or ideas, is artificial and is motivated to satisfy the financier or an administrator.

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Without this study of the thermodynamics and of the phenomenon of catalysis, there would be no synthetic ammonium sulphate. I am particularly stressing this point, because at the time when Haber, made the above theoretical studies, he had perhaps no clear idea of the application of these in agriculture Agriculture and thermodynamics appear so remote from each other.

Chemistry and crop protection : At the present time, chemicals provide the most effective means of protecting crops from pests, diseases and weeds. Established fungal infections can be attacked directly and seeds may be treated with a chemical to control seed-borne diseases or protect them against soil-borne fungi. However, no real progress can be made in the application of chemistry to crop protection without healthy collaboration between the chemist and specialists from other disciplines, particularly the biologist. For it is the biologist who must decide from a study of the life history of the parasite the most vulnerable stage of development at which chemical application should be made.

New pesticides are developed at considerable cost usually in the laboratories of commercial concerns. Many of the compounds are screened each year as insecticides, herbicides, fungicides and so on. When a compound is discovered which shows useful activity, a large number of structural analogues are synthesized and screened. The best material is sent out for field trials. Simultaneously, the physical and chemical properties are intensively studied. It is ensured that the compound is stable during storage and on exposure to light and humid conditons etc. The phyto-toxicity of the compound is also studied. When the compound meets all these requirements, fundamental studies on the mode of action are undertaken by a team of specialists. Possible hazards to health resulting from the residues left over on the crop have also to be taken into account.

The use of organic pesticides has posed another problem; whereas, the older inorganic materials, such as lead arsenate and bordeaux mixture seldom entered into the plant and the residual material could be removed, the organic pesticide can penetrate into the plant tissues e.g. some organo-mercurials can move through the skin and into the pulp of

person so profoundly as the growing field of synthetic fibres.

Viscose *rayon*, the earliest synthetic fibre to appear on the market was viscose rayon which was obtained from the natural polymer, cellulose, through modification of its properties. Cellulose acetate produced by the viscose process proved to be an instant success. These fibres were sold under the name of artificial silk. In 1927, the Du Pont Co. inaugurated a fundamental research programme which was to result in the first true synthetic fibre to achieve commercial importance, nylon. The development of fully synthetic (chemical) fibres permitted the formation of polymers having properties decidedly different from those of naturally occurring cellulose and protein polymers. Nylon, is a polyamide fibre. The polymer is produced by the reaction of adipic acid and hexa-methylene diamine, followed by polymerization to the desired molecular weight. The polymer is melted, forced through minute openings. Nylon was placed on the market in 1938. It possesses many of the properties of natural silk. It was immediately pressed into military uses for fabrication of parachutes and glider tow ropes as soon as the supplies of natural silk were cut off as a result of war with Japan. Nylon cords are extensively used in airplane tyres, heavy duty tyres and truck tyres. Other synthetic fibres include Arcilan, Dacron, Orlon and Dynel. By skillful blending of these and natural fibres the Textile Industry is preparing fabrics and other consumer items in which new styling, comfort and durability standards are being attained.

Fibres have also been prepared from alginic acid derived from sea weed and from casine, the protein of milk.

It is needless for me to point out that with the development of synthetic fibres, the demand for cotton and wool will decrease and greater areas of agriculture can be put under food crops.

Synthetic fertilizers : The development of ammonium sulphate, one of the major fertilizers, bears eloquent testimoney to the role basic research has played in Agriculture. It was the painstaking studies of Haber on the thermodynamics of the reaction $N_2+3H_2=2NH_3$ which finally resulted in the successful synthesis of ammonia from nitrogen and hydrogen.

Without this study of the thermodynamics and of the phenomenon of catalysis, there would be no synthetic ammonium sulphate. I am particularly stressing this point, because at the time when Haber, made the above theoretical studies, he had perhaps no clear idea of the application of these in agriculture Agriculture and thermodynamics appear so remote from each other.

Chemistry and crop protection : At the present time, chemicals provide the most effective means of protecting crops from pests, diseases and weeds. Established fungal infections can be attacked directly and seeds may be treated with a chemical to control seed-borne diseases or protect them against soil-borne fungi. However, no real progress can be made in the application of chemistry to crop protection without healthy collaboration between the chemist and specialists from other disciplines, particularly the biologist. For it is the biologist who must decide from a study of the life history of the parasite the most vulnerable stage of development at which chemical application should be made.

New pesticides are developed at considerable cost usually in the laboratories of commercial concerns. Many of the compounds are screened each year as insecticides, herbicides, fungicides and so on. When a compound is discovered which shows useful activity, a large number of structural analogues are synthesized and screened. The best material is sent out for field trials. Simultaneously, the physical and chemical properties are intensively studied. It is ensured that the compound is stable during storage and on exposure to light and humid conditons etc. The phyto-toxicity of the compound is also studied. When the compound meets all these requirements, fundamental studies on the mode of action are undertaken by a team of specialists. Possible hazards to health resulting from the residues left over on the crop have also to be taken into account.

The use of organic pesticides has posed another problem; whereas, the older inorganic materials, such as lead arsenate and bordeaux mixture seldom entered into the plant and the residual material could be removed, the organic pesticide can penetrate into the plant tissues e.g. some organo-mercurials can move through the skin and into the pulp of

the tomato fruit as also DDT is dissolved in the waxy blossom of apple. Sometimes this is advantageous as the pesticides may not be easily washed away and hence the effect is more prolonged.

Ion exchange resins : In 1934, Adams and Holmes discovered at the then National Chemical Laboratory of U.K. that phenol formaldehyde and aniline formaldehyde resins could be used for ion exchange reactions. They also demonstrated that water could be deionized by passing it through the heads of these resins. Industry now extensively employs ion exchangers for demineralization of water in place of distillation. There are distinct potentialities of this process being extended to the desalting of sea water. This single factor could radically transform and revolutionize agriculture leading to the reclamation of large tracts of deserts. Another important use to which ion-exchange resins have been put is in the field of hydrometallurgy. In these processes; anion exchange has proved to be a more powerful and versatile method of recovery and separation than cation exchange. The metals which are desired to be separated by ion-exchange readily form anionic complexes and can, therefore, be absorbed selectively from a solution containing metals which do not form complexes. At the National Chemical Laboratory of U.K. detailed basic studies were undertaken on the use of anion exchange resins for the recovery of uranium and gold from dilute solutions.

Synthetic vitamins : The story of the vitamins is a very fascinating one. In the beginning, monumental efforts were needed to isolate and characterize the vitamins. To quote examples, R. Kuhn started with 33,000 eggs to isolate only 100 mg. of vit. B_2. R. Williams needed a 30,000 fold concentration of rice polish for isolation of vitamin B_1. If the matter had been allowed to rest there, we would still be deprived of the beneficial effects of the vitamins. But, by continued research into the chemistry of vitamins, their structures were established and economic methods for their synthesis were evolved in many cases. The structure of vitamin B_1 was established in 1936. By 1957, the compound was commercially available at $ 40/kg., which amounted to about 500,000 daily allowances. Vitamin C was first isolated in 1879 from milk. Its structure was

established in 1935 and synthetic vitamin was available at $ 40/kg. by 1957. Today you can buy synthetic vitamin C at a fraction of what it would cost to obtain it from a natural source.

Synthetic detergents : Conventional soaps result from the action of alkali on natural fats, with glycerol as the by-product. The organic chemist can now manufacture synthetic detergents, which perform the same function as soap, but do not require the natural fats. Consequently, the much needed fats will be spared for the hungry millions of the world.

Food flavours : Flavour has an asthetic value in food. Even the most nutritious foods would be unacceptable if they did not have the right type of flavour. An impurity of less than one part per million in water renders the food unacceptable. The presence of an off-flavour can considerably detract from the value of a food.

With the development of gas chromatographic methods for analysis of flavour components, it is not only possible to know practically all the chemical compounds which constitute flavour; but also the proportion in which they are present. As a result, synthetic flavours are now available on the market. For example, you can buy a cup of straw-berry ice-cream, which contains no straw-beries whatsoever. The ice-creams flavoured with the synthetics are far cheaper. It can be safely anticipated that in due course synthetics will find their way into tea and coffee. This will result in cheaper tea and even the poor people will be able to afford tea with Darjeeling flavour.

Preservation of food by irradiation : This is one of the newest methods of preserving foods. For this purpose either the penetrating α and X-rays or the less penetrating β-rays have been used. β-particles are actually electrons emitted from nuclei of radio-active atoms during their decay processes. For sterilization of food, energy levels above 1,000,000 volts are needed. The shelf life of such materials as a hamburger has been extended from 1 week to 1 year by this type of treatment.

Adversity—the mother of invention : The history of

mankind records many examples where human ingenuity has overcome almost insuperable difficulties. During the Second World War as a result of the occupation of the rubber producing East Indies by the Japanese, the allies developed synthetic rubber. The Germans, faced with a similar situation evolved the Fischer-Tropsch process for the manufacture of synthetic petroleum from coal. Now that proteins are being prepared from petroleum, the possibility of production of protein from coal cannot be lightly set aside. After the First World War, when the Germans were deprived of the supplies of Chilean salt, they developed a process for the synthesis of nitric acid by passing an electric arc through the atmosphere. The supplies of quinine, the only anti-malarial known before the Second World War, were cut off as a result of the Japanese occupation of Malaya. This stimulated research in the field of synthetic anti-malarials, so that today we are no longer dependent on the natural product.

Synthetic dyes : Before the development of synthetic organic chemistry, natural dyes from plant sources were exclusively used for dyeing of cotton and woollen fabrics. Indigo and tyrian purple were important items of commerce in early history. The latter dye was so precious that only royalty could use it hence the term 'royal purple'. The organic chemist of today can synthesize dyes to meet special requirements. We have ingrain dyes which are formed right in the fibres of the fabrics (e.g. para red), mordant dyes which are bound to the cloth via complex agents or the mordant (e.g. Alizarian) the Vat dyes, which exist as colourless, water soluble lecuoform, which on exposure to air are converted to coloured insoluble dyes. One of the oldest such dyes is indigo. The synthesis of indigo was a hall mark in the history of organic chemistry. It demonstrated the power of synthetic organic chemistry to the layman. The well established plantation industry of indigo finally went out of existence. (I would not be surprised if coffee and rubber plantations meet the same eventual fate as indigo).

The first synthetic dye was a triphenyl methane dye. This was prepared unintentionally (1856) by William Henry Perkin, a student in Hoffmann's laboratory. During the course of his study on the oxidation of aniline, Perkin isolated a product which could dye wool and silk. Perkin started a

factory for the manufacture of this new dye, which was called mauve. This was the beginning of the coal-tar dye industry which has developed considerably. In 1956, a hundred years after the discovery of mauve, 152,000,000 lb. of dyes valued at $ 185,000,000 were produced in U.S.A. alone.

Dye-stuffs derived from coal-tar chemicals are being screened for carcenogenic activity because these are being used in foodstuffs.

I have tried to show by a few examples how great practical benefits have accrued to mankind as a result of basic research undertaken primarily for intellectual pursuits. I think that the best way to evaluate the role of basic sciences in agriculture will be to see in what shape modern agriculture would be without the benefits of chemical fertilizers and chemical plant protection measures etc.

Chapter VI

Plant Introduction—Past, Present and Future

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Plant introduction has been and shall continue to be the major consideration in man's endeavours to exploit to the maximum all that the vast vegetation on the earth has to offer for his well-being. The movement of plants has had both good and ill effects. Whereas the movement made it possible for the nations of the world to have a rich variety of food plants and plants which led to the establishment of flourishing industries, it also has been responsible for creating problems in agriculture through the introduction of abnoxious weeds and harmful insect-pests and diseases. No doubt, man himself is to be blamed for this unhappy situation.

Plant introduction defined : For a proper understanding of the past, present and future of plant introduction it is desirable to analyse the various definitions of plant introduction. The various definitions proposed seem to be appropriate in relation to the periods through which plant introduction has passed and is expected to pass in future. It has been suggested that plant introduction may be taken to mean in its broadest sense, introduction of wild plants into cultivation. It was undoubtedly exclusively this for many centuries, if not mellenia, since the birth of agriculture. This has continued and as the modern trend appears to be, there will be renewed search for wild plants which can be developed as new agricultural plants mainly for industrial purposes to meet new and more exacting demands. This is

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the present trend in the more advanced countries such as the U.S.A. and U.S.S.R.

After the selection of useful plants made by the ancient man and with the subsequent rise of civilization in many lands resulting in better contacts between peoples, these useful plants found their way into new lands. Here a distinction can be made between 'primary', and 'secondary' plant introductions. The introduction of wild plants into cultivation and the successful transfer of cultivars with their genotypes unaltered to new environments could together be designated as 'primary' plant introduction and the rest as 'secondary'.

An all involving definition Frankel puts it as "transposition of a genetic entity from an environment to which it is attuned to one in which it is untried". This is in fact the sense in which plant introduction is understood by many. But it is not necessarily always from a foreign country. Also the term 'environment' in this definition can, in addition, mean 'internal genetic environment' also. It thus includes transfer, addition or substitution of genes, chromosome segments or entire chromosomes brought about through near or distant hybridisation by employing a wide array of techniques such as back-crossing, embryo culture and polyploidy and even mutations and structural alterations of chromosomes. Thus it encompasses the entire gamut of modern plant breeding techniques, ultimate goal of which is introduction of improved varieties of plants into cultivation anywhere in the world. This is what ought to be the outlook and approach of a modern plant introduction botanist and a plant introduction organization. Plant introduction, therefore, does not in reality stop with the exchange of plant material as some of us might like to suggest.

Plant introduction by primitive men : Man has depended on plants ever since he appeared on earth. This association has continued to the advantage of both. The primitive man selected useful plants with his own rough techniques. These plants remained wild for long till their adoption as cultivated plants. It was a splended job done.

These useful plants have now been determined to be inhabitants originally of certain pockets called

centres of origin which are eight in number according to the Russian Geneticist, Vavilow, who has contributed much to our knowledge of the subject. When we consider that these centres do not occupy more than 1/40th of the land surface and when we realise that almost every known economic plant is now widely distributed, it is obvious that the various plants have moved or have been made to move to distant lands in different times. No doubt, therefore, that plant introduction makes a long and romantic story. The Centres found favourably for the domestication of these plants also favoured the development of human civilization. Thus we see that in the seats of ancient civilization a few food plants were of basic importance to man e.g., maize in Mexico, wheat and barely in the Mediterranean basin and South-West Asia and rice in India and China. Almost all the food plants and a variety of others were selected in prehistoric times and have been cultivated for long.

In historic times : The transfer of plants from one region to the other must have been slow in early periods. Nevertheless the movement of plants originating in parts of the old world was possible among the old world countries much earlier because of geographic contact but the exchange between new world and old world was possible only after the discovery of Americas by Colombus in 1492, and the European colonisation soon after. It is, therefore, not surprising that America which is now the principal exporter of wheat with an annual production of 35 million metric tons did not have this old world cereal about 400 years ago. So was the case with rice. The new world cereal, maize similarly is now an important cereal in the old world. There is a full list of old world and new world economic plants which have been exchanged not only between western and eastern hemispheres but also among countries constituting the two hemispheres.

The last five centuries have witnessed much give and take among the economically useful flora of different regions in the world. This exchange in the beginning was mostly at the species level and was made in an empirical way but it has to be appreciated that even so, the achievement has been no less significant. During the 16th century and later, the Portuguese, English, French and Dutch, in the process of colonization, introduced many plants into different lands.

The Mohammedan rulers were similarly responsible for a variety of plants introduced into new areas of their conquests. Thus we know of the introduction into India by Portuguese of crops such as groundnut, maize, chilli, potato and fruits such as guava, papaya, pineapple, cashewnut and some others.

In more recent times : During the last 150 years there has been further accelerated plant introduction work mainly for the introduction of new species. Several reputed institutions and organizations entered this field of activity.

The World famous Kew Garden in U.K. was set up in 1841, about 50 years after the Calcutta Botanic Garden set up by the East India Company. The Kew botanists were responsible for the collection of seeds of cinchona and rubber plants from South America. The Indian Botanic Garden at Calcutta did similar good work in India and was responsible for introducing plants such as Sapota and Avocado from West Indies, *litchi* and *loquat* from China and Mangosteen from Malaya, besides the valuable timber tree Mahogony. During the latter part of the 19th century and early part of the present century many plant explorers and plant collecting expeditions were actively engaged in the collection of agricultural and garden plants. The names of British explorers such as Fortune, Wilson, Forrest, Farrar and Kingdon-Ward are well-known for exploration in Far East particularly in China, which country is called the "Mother of Gardens", by Europe. Amongst the American explorers, Fairchild, Rock, Meyer and more recently Gentry and others were well-known agricultural plant explorers. Vavilov and his associates explored in more than 60 countries during the early part of the present century. There have been at least nine potato collecting expeditions to South America. The Australians have explored in Mediterranean area and in South America for pasture plant introductions.

The activities of the agricultural departments in the field of plant introduction started mostly during the present century. Some of the Agricultural Departments in India were set up in 1905 or so. The U.S.D.A. was started in 1862.

In the introduction of new economic species into India after the discovery of Americas the Portuguese introduced many valuable plants from the new world. The East India

Company set up the Royal Botanic Garden at Calcutta, in 1786, and several other botanic gardens at Saharanpur, Poona, and other places and introduced a variety of plants from China, South America and other parts. The Royal Botanic Garden in association with the Royal Botanic Garden at Kew were responsible for the introduction of cinchona and rubber. The Agricultural Departments which set up in the early years of the present century were also responsible for the introduction of new species such as the Egyptian clover, Tung tree, American cotton and others.

Present trends : In recent years the plant breeders and other plant scientists have realised that a stage has reached where the introduction of altogether new economic species has limited possibilities but there is a much wider scope in improving the agronomic potential of the presently grown economic species by effecting genetic improvement through a more judicious use of extensive germplasm. Therefore, greater emphasis has been laid on location and assemblage of varietal wealth through correspondence or through exploration.

This exchange of plant material, on a worldwide basis, has been mostly carried out without regard to any well-defined procedures but several countries such as the U.S.A., U.S.S.R., Australia and a few others took a lead in establishing plant introduction organizations for channelising import and export of plant materials. Plant Introduction Organizations now exist in several other countries also.

The present activities in plant introduction aim at (a) exploring the possibilities of utilising what is known as readymade varieties and (b) utilizing the introduced genetic stocks in hybridization or for providing populations for selection. There are scores of good examples of readymade varieties having been adopted in new lands and which have held the field for long as direct introductions. We have a very recent example of the Mexican wheats and Taiwan paddies and we know very well how much stir these have caused among the wheat and rice breeders and the growers in India. But the availability of readymade varieties is not always the right answer. A much greater scope lies in manipulating the available germplasm to breed varieties with still higher potential. This is how we now have the new

composite maize hybrids which have just been released in India. These composites combine the best of maize germplasm and it has been claimed that if properly maintained these can do away with the more laborious procedures for hybrid seed production. The development of such composites and synthetics can be possible also in several other crop plants. In India exotic germplasm is being advantageously used in the case of cotton (Russian material), wheat, millets, and some other crops. Modern plant breeding theory lays greater emphasis on broad genetic base whether it is production breeding or resistance breeding.

In the present approach to plant introduction that is being made by some of the agriculturally advanced countries such as the USA and USSR special importance is being attached to the continued maintenance of worldwide germplasm. This is undoubtedly the more important phase of plant introduction work because it is not easy to make collections as and when required. Collections can be used any time a new problem faces the breeders, as it had happened in the case of rust diseases of wheat and oats in USA with the occurrence of new races.

In addition to the naturally occurring gene centres there are many useful man made sources of rich germplasm :

Leningrad	..	1,60,000 living specimens of crop plants except fruits.
Kew	..	45,000
Maize	..	Hungary, Mexico, Columbia and Brazil.
Wheat	..	3,90,000 throughout the world.
Sugarcane	..	Canal Point Florida and Coimbatore.
Groundnut	..	Senegal.
Potato	..	Cambridge University and Wisconsin.

In future : It is obvious that the present rate of free exchange of plant material for use in crop improvement programmes will be much accelerated in years to come. The exchange of plant material on that big scale, throughout the world, would be possible to the best advantage only if this work is entrusted to organized plant introduction services. In India such a service exists under the Ministry of Food & Agriculture at the Indian Agricultural Research Institute.

This National service requires to be suitably strengthened. It is also necessary to make a legal provision so that exchange of plant material is well regulated. This organisation has done much useful work in the location and utilisation of useful genetic stocks in agri-horticultural crops. Several varieties of crops such as wheat, oat, vegetables and fruits besides forage plants are now popular with the farmers. While strengthening the plant introduction organisation due consideration has to be given to augmenting the plant quarantine units and to have well-integrated programme with the Plant Protection Directorate so that the whole country falls in line. We are already hearing of the golden nematode and wart disease of potato, virus diseases of citrus and also of grape which are recent reports. There could be many more such reports in future if we neglect this all important aspect of plant quarantine.

Plant exploration by sending out field parties for collection of germplasm shall have its own role to play as it has done in the past. It would be desirable to prepare a band of young botanists to enter this field of activity. Explorations are expensive but a modest provision must be made. In plant introduction work personal contacts matter a lot. Therefore, every opportunity for establishing such contacts should be availed. Plant introduction men should find opportunities to visit foreign lands to establish contacts and to see plants on the spot.

There is frequent reference of gene erosion not only from primary or secondary centres of origin but also from general areas of cultivation of different agri-horticultural crops. Future plant introduction work, therefore, has to be linked up with the maintenance of the gene pool. To that extent efficient seed storage facilities in different parts of the world are an essential requirement. It is doubtful if we, in India, have been able to conserve the natural rich variability that existed in our crop plants two to three decades ago. Future plant introduction work will also take into consideration the agri-phytochemical aspect with a view to locate new plants for developing as additional economic plants for exploitation in industries based on agricultural products. Therefore, there is need for a reasonably equipped agri-phytochemical laboratory. Indian vegetation offers good material to feed such a laboratory for gainful results.

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From the Wild to the Cultivated Plant

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Tracing back the history of cultivated plants has always been a Herculean job but at the same time interesting and rewarding. Early students of biology have always wondered about the origin of a plant. In recent years much progress has been made in this direction, but still many things are not yet known. In most cases, the origin of plants is still based on theories and assumptions. In this paper an attempt has been made to mention how the wild plants became cultivated and the usefulness of wild plants in present day research.

The term 'cultivated plants' includes a very large group of plants. This group of plants plays an important role in the agricultural and industrial economy of mankind. All crop plants, with the possible exception of bread wheat and a few others, were domesticated during agricultural revolution of Neolithic times. Neolithic man had the first choice to pick and choose and investigate the germplasm of the plant kingdom so thoroughly and methodically that nothing special has been added since then.

The whole group of cultivated plants consisting of primary crops, secondary weed crops and others have developed in the present form in the last 5,000 to 7,000 years. Rice and maize and a few others were probably cultivated at a much later date. The credit goes to the diligence of man in sorting out and preserving interesting and profitable variants. Since the domestication of these plants very little change has been noticed. This view has been supported by Harlan (1957) who stated that barely types have changed little during the past 5,000 years. However, it is difficult

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to suggest the time involved in the change from wild species to cultivated forms.

The classic work of Darwin on 'The Origin of Species', published in 1859 was the first attempt to throw light on this topic. Darwin was interested in domesticated animals and cultivated plants as he thought that it may teach us about evolution. He was impressed by their great variability and by the magnitude of their differences from their wild progenitors. In recent years, geneticists and evolutionists have turned their interest on the cultivated plants as evolutionary subject.

de Candolle was the first to really make a serious attempt on the origin of cultivated plants. His book 'The Origin of Cultivated Plants', was published some 80 years ago but the information contained in the book is modern and up-to-date (1886). The Russian Scientist Vavilov (1926) made the next serious attempt. The most important contribution of Vavilov is considered to be that he proposed the concept of geographic centres of variability or gene centres. Later discoveries have revealed that whatever Vavilov pointed out is not always true but this does not minimise the importance of Vavilovian work. Since Vavilov, comprehensive treatment on the origin of cultivated plants has been made.

The species were evolved chiefly through three main ways : (1) Mendelian variation (2) interspecific hybridization and (3) polyploidy. This, however, is not a complete list and those interested in details are referred the book 'Variation and Evolution in Plants' by Stebbins (1959). Mendelian diversity arises basically through gene mutations which are the building blocks of evolution. Recombinations arising from hybridization among types carrying different mutations cause further diversity among individuals upon which both natural and artificial selection is based. Sometimes a single mutation with drastic effect may substantially increase the usefulness of a species to man. Heading cabbage, cauliflower, broccoli, brussels sprouts and kohlravi have all been derived fairly directly from wild cabbage through macromutation. The morphological differences present in these crops depend on few gene differences. Many ther crops which appear to have developed through variation within a single species are rice, maize, barley, beans, tomatoes,

flax etc. Each of these species has developed in its own way but the general pattern is the Mendelian variation.

A second method of evolution of cultivated plants depends on the crossing of distinct taxonomic species. A large number of gene differences are likely to occur in interspecific hybrids coupled with differences in chromosome organization. Many of the recombinants are difficult to preserve and select upon. Vegetative propatation preserves the exceptional vigour which characterizes many F_1 interspecific hybrids. Certain varieties of pear, plum, grapes and cherries have arisen from interspecific hybridization. Also certain ornamentals like roses and lillies are the product of interspecific hybridization. Another form of interspecific hybridization namely *interogressive hybridization*, might have been in operation in certain cases. In this case, hybridization is followed by recrossing with parental species in such a way that certain characters of one species become transferred to another one without impairment of taxonomic integrity. In other words, one species becomes enriched to some extent by the genes of the other species. Introgression is difficult to detect particularly when it is slow and the whole matter depends on speculation.

The third form of evolution that has been important in the development of cultivated plants has been polyploidy. In polyploidy, the variation arises through reduplication of chromosome sets. Meiotic irregularity may give rise to triploids, tetraploids or even higher level of polyploidy. It is of two types viz. *autopolyploid* when identical genomes of a single species are duplicated and *allopolyploid* when genomes are dissimilar arising from two or more species. A few examples of *autoployploids* are commercial bananas which are triploid (2n—33) and potatoes which are tetraploid (4n—48). Some outstanding examples of alloplyploids are wheat, tobacco and cotton.

It will be more appropriate to deal with the subject by taking specific examples to demonstrate how a plant, wild at one time, became cultivated. Kihara discovered the origin of hexaploid bread wheat based on his investigation of genome homologies of wheat and wheat relatives. According to Kihara's classification the diploid wheats, both wild and tame, have the genome constitution AA. Most of the tetraploid

sheats, wild and domesticated, have the constitution AABB while the common cultivated hexaploid has the constitution AABBDD. Kihara (1944) and McFadden and Sears (1946) demonstrated independently that D genome comes from *Aegilops squarrosa*. Sarkar and Stebbins (1956) found *Ae speltoides* as the source of B genome. In the case of wheat, the weed forms are species of *secale, Haynalida, Aegilops* and possibly *Agropyron*. I would like to emphasize one point here that we know hexaploid bread wheat contains heredities of *Triticum monococcum, Triticum speltoides* (*Aegilous speltoid*) and *Triticum aegilops* (*Aegilops squarrosa*) but hardly one wheat breeder in a hundred has seen all the three species and not even one in a thousand has seen them in their native habitat.

Although the origin of new world cotton is still controversal, the hypothesis of Skovsted (1934, 1937) is accepted mostly. According to him new world American cotton (*Gossypium hirsutum* 2nd=52) arose through allopolyploidy from a hybrid or hybrids of Asiatic cotton (*Gossypium arboreum*, 2n=26) and American cotton (*G. thurberi*, 2n=26). This fact has been partially supported by Beasley ((1940).

According to Sampath and Narsinga Rao (1951) *Oryza perennis* is the ancestral form of cultivated rices giving rise to *O. sativa* in Asia and *O. glaberrima* in Africa by selection. The crossing studies suggest that they are no different from *indica* and *japonica* varieties of *O. sativa*. It is interesting to note that both the African and Asian rices have their own weed forms, that is, *O. breviligulata* and *O. satia* var. *fatua* respectively. According to Chatterjee (1948) there are 23 species in the genus *Oryza;* of these 21 are wild and 2 cultivated. In both cultivated and wild forms introgression is obvious.

In case of maize, the wild plant form, is not yet known. It is assumed that the wild maize plant might have become extinct. Teosinte is usually regarded as very closely related to maize, therefore, any satisfactory explanation on the origin of maize must account for its close relationship with teosinte. Both teosinte and *Tripsacum* seem to have played an important role in the origin and evaluation of maize (Harland 1961). The geographic origin is considered to be somewhere in the tropics of Central and South America.

To trace out the origin of sugarcane, extensive work has been done on sugarcane in India or elsewhere. Based on cytogenetical work, Parthsasarthy (1946) suggested that Indian canes have arisen by extensive hybridization between *S. officinarum* and *S. spontaneum* in the regions of Bihar, Bengal and Orissa. This fact has been further verified by Mukherjee (1949) *in his discovery of natural hybrids of these* species in a wild state in Orissa.

Turning to the origin of fruit plants, Chakravorti (1951) has concluded that all the cultivated varieties of bananas have descended from two wild and variable species occurring in S. E. Asia. They are split up in three groups according to their ancestry. The members of the first group are believed to have originated from *Musa accuminata* Colla, the second from *M. balbisiana* Colla and the third from the hybrids of the above two species. The wild species are diploid (2n=22) while a great majority of edible bananas are triploids (7n=33) and only a few of them are diploid. It is believed that parthenocarpy and female sterility developed as gene mutations in the fertile diploid. The resultant type propagated only through vegetative means.

According to Mukherjee (1951), the origin of the mango (*Mangifera indica*) is believed to be in South Asia. Its probable wild ancester appears to be *M. sylvastica* and *M. coloneura*. Bhattacharya and Dutt (1951) have suggested that *citrus indica, Citrus latipes, Citrus microptera* and *C ichangensis* are native of Assam. The wild forms of some of the selected important crops are listed in Table 1.

TABLE I

Wild form of some of the selected plants

Crops	*Weed forms*
Wheat, *Triticum spp.* ..	*Secale cereale, Haynalidia villosa Aegilops* spp., *Agropyron* spp.
New World American Cotton, *Gossypium hirsutum*	Asiatic Cotton (*G. arboreum*) and American Cotton (*G. thurberi*) cultivated forms.

Crops		Weed forms
Rice oriental, *Oryza sativa*	..	Red rice or wild rice, *O. sativa* var. *fatua*.
Rice, African, *O. glaberrima*	..	Wild rice, *O. breviligulata*.
Maize, *Zea mays*	..	Teosinte, *Z. mexicana*.
Barley, *Hordeum vulgara*	..	*H. spontaneum*, *H. agrocrithan*.
Oat, *Avena sativa*	..	*A. sativa* var. *fatua* and *Avena* spp.
Sugarcane, *Saccharum officinarum*		*S. sponianeum* and *S. officinarum*.
Banana, *Muva supientum*	..	*Musa acuminata* Colla and *M. bulbisiana* and their hybrids.
Mango, *Mangifera indica*	..	*M. sylvastica* and *M. coloneura*.

Coming back to the work of Vavilov, it is necessary to mention his contribution to our knowledge of geographical origin. He proposed eight centres of diversity : China, Hindustan, Central Asia, Asia Minor, Mediterranean region Abyssinia, Central America and West Central South America. The proposed centre of origin coincided with the area where greatest amount of diversity exists for the species. His convinction was that the variety grown in the centre of origin usually contained a large number of dominant genes. Vavilov further proposed the secondary centre of origin where two or more species crossed freely and subsequently selection followed. Although proposed Vavilovian centres are not fully recognized by all, they still serve as fertile collecting areas. Harland (1951) during a plant collecting expedition to Turkey in 1948 was much impressed in the plant diversity in smaller areas within the 'centre of origin' of Vavilov. These he referred as 'microcentres'. Certain of the microcentres offer excellent ground to study evolutionary changes in the present day.

To confine our collection of germplasms for breeding purposes from the primary centres of origin would not be sufficient and appropriate. Some workers have suggested the idea of diffuse origin which means we can never solve the problem of geographic origin of cultivated plants. The crop plants did not originate at one place and they are still in a process of evolution wherever they are being raised. The centres of diversity are the centres of most active origination (Harlan, 1951). The mango, *Mangifera indica* appears to have originated in Malaya but India is said to be the area of

greatest varietal diversity. Other examples can also be quoted but the point to emphasize here is that it is difficult to pin point the origin of species of a particular plant.

World collections of cultivated plants have been assembled primarily as gene pool from where a plant breeder can directly draw the material for his use. Collection of widely divergent germplasm should be considered as a source of genetic material which would be useful in altering the course of further development. There is a great urgency to collect gene pools as quickly as possible from the places of extreme diversity before they are wiped out as the new varieties are replacing the indigenous ones very quickly. It is emphasized that a vigorous programme of exploration, collection and maintenance of germplasm should be taken up.

It is important to know why the origin of plants is of immense value in the improvement of agriculture. Firstly, it helps us to understand how a particular group of plants may be introduced. Anderson and Brown (1952) pointed out that if the corn belt originated in the United States by introgression of the northern flints and southern dents, then we might expect to obtain maximum heterosis by developing inbreds with many of the characteristics of these diverse groups. It would be beneficial in planning out work if one knew that a particular plant originated by introgression from other species or from the wild form. If a specific gene or block of genes cannot be transferred through conventional methods then some other methods like substituted chromosome, induced translocation etc., may be tried.

Secondly, knowledge of where and how and by what means a plant is introduced into cultivation could be useful in the development of beneficial plants. Most of our useful plants were added during the Neolithic period and only a few are of recent origin. The latter ones are mostly useful in medicine, industry and manufacture of insecticides. Research is under way to find out new uses of wild and cultivated plants for industrial purposes. Fodder breeders who are working with wild or near wild species can make better use of such information.

Thirdly, knowledge of crop geography tells us where to look for the diversity which could be used in breeding pro-

grammes. Centres of diversity are the best places to look for wealth of this material.

Finally, the knowledge of wild forms is immensely useful in our research work. High resistance to diseases and cytoplasmic male sterility for the production of hybrid wheat have been introduced in wheat from weeds. Wild tomatoes and wild potatoes have contributed significantly for the improvement of these crops. To give a final example, the sugarcane industry has been rescued twice by infusion of germplasm from *Saccharum spontaneum*, one of the objectionable weeds of India and generally a menance rather than a benefit to agriculture. In the future too, the wild forms will continue to provide invaluable genes for agricultural and industrial improvement.

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Development of Plant Breeding Concepts and Techniques

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Activity of directing plant evolution towards man's needs is plant breeding. It began with the domestication of the plants under controlled conditions, when the importance of seed as a progenitor of the next generation was realised. *Manu Smriti* an old record of Indian civilization proclaimed 'Subeejam Sukshetre Jayate Sampadyte', that is good seed in good field yields abundent produce. This knowledge, that good seed is essential for good harvest led to the conscious efforts, for selecting types which may provide dependable source of food. First of all selection was made between different plant species available in a particular habitat, and then it was directed towards the establishment of superior types within a particular species. The former is essentially responsible for all our food and industrial crops, while the latter gave us a large spectrum of forms known as varieties adapted to specific agro-climatic conditions.

The early plant breeding prior to the discovery of Mendel's laws was mainly a matter of personal fancy and not a systematic organised effort. It was mainly an art, since the plant types were forged in a mold conforming to an image of an ideal plant, which varied with person to person and depended heavily on the power of observation and the experience of the breeder. This difference of skill between the primitive societies was evident from the fact that the inhabitants of the bat cave in New Mexico from 2500 B.C. to 500 A.D.

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did not succeed in eliminating the small size of primitive corn, while only with difference of 500 to 1000 years the selection for large ears of maize by the American Indians seems to have resulted in the varieties which had uniformly large ear size approaching present days maize.

Also the samples of lima beans found in the ruins of some of the oldest red Indian civilizations of Peru have seed that are nearly 100 times as large as those of wild limas of that area. This apparently indicates the great plant breeding ability of Pre-Incan Indians of Peru.

The improvement in crop plants made by some of the early civilizations was mainly through the process of introduction and mass selection, which is based on the natural tendency of preserving the seeds with large size of plants with large number of seeds.

However, modern plant breeding procedures are based on the sound knowledge of the genetic principles and the inheritance pattern of different characteristics, and, therefore, can be pursued with objectivity and predictability. Just after the rediscovery of Mendel's laws in 1900 the emphasis was on the qualitative characteristics with simple inheritance such as colour, obvious changes in form and resistance to diseases. More recently, the genetic studies have ellucidated the inheritance pattern of quantitative characteristics which are controlled by comparatively large number of genes with small individual effects such as yield, height and maturity.

Now not only the genetic laws governing the qualitative and quantitative characters have been understood, but considerable knowledge has been acquired about the primary nature of genes and their intricate association with the chromosomes the carriers of heredity, which equip the present day plant breeder with the capacity of manipulating plant heredity at the chromosome as well as at the gene level with appropriate techniques.

Hence the major plant breeding approaches currently in vogue involve :

1. *Simple Mendelian Genetics.*
2. Biometrical genetics.

3. Cytogenetics.

The choice of a particular approach depends on the available germplasm, inheritance pattern of the characteristics to be improved and the breeding objectives in sight.

As regards the availability of germplasm, nature has sustained a tremendous amount of variation in crop plants on which natural and artificial selection acting together have established forms, which suit a particular agro-climatic condition. In situations where this natural wealth of variation is readily available to a plant breeder his main task remains to screen and select the most outstanding and desirable material through simple technique of pure line selection. However, Johannsen's (1903) brilliant experiment with lima beans showed most convincingly, the limitations of pure line selection, viz., (1) selection can act effectively on heritable difference, (2) selection cannot create variability but acts only on that already in existence. Therefore, as soon as the available variability is exhausted evolutionary factors, viz. Mendelian variation, interspecific hybridization, polyploidy and mutation figure more prominantly in plant breeders approach to make further progress.

Breeding self-pollinated crops : The idea of hybridization in crop plants originated as early as 1964 when Camerarius first demonstrated the presence of sex in plants and suggested crossing of two parents to get new types. But its extensive use to combine the desirable characteristics from two parents started only after Biffen's report in 1905, that resistance to strip rust in wheat was controlled by a single recessive gene, and it was possible to develop a resistant variety by crossing the resistant and the susceptible parents. Early efforts to imprve the stem rust resistance of wheat were begun by Freeman in cooperation with Kansas and Minnesota stations in U.S.A. shortly after 1904. Hayes and his co-workers in 1920 successfully transferred durum stem rust resistance to bread wheats in the famous Marquis x Iumillo cross (Smith, 1966).

In case of self-pollinating crops, ultimate aim after hybridization has been the development of a pure line as a variety. To achieve this end, three breeding methods have been successfully utilized in handling segregating generations

of a cross, viz., (1) Pedigree method, (2) Bulk method and (3) Backcross method. Out of the three basic methods of handling segregating materials, the pedigree procedure has been the most widely used. In this method plants which have the desired characteristics of the two parents are selected in the successive segregating generation and a record is maintained of all parent progeny relationships. In large plant breeding programmes it was sometimes difficult to maintain long pedigree records, and also it was not possible to handle large number of crosses by this method in available resources of land and finances. Bulk method of breeding which was first used by Nilsson-Ehle of Sweden for handling segregating generations of a hybrid made to combine winter hardiness of the square head variety with the high yield of the stand-up variety of winter wheat seemed to solve the difficulties of the pedigree method. Since the segregating F_2 generation is planted in a single large plot, and at maturity the plot is harvested in bulk and the seeds used to plant a similar plot the following season. This process is repeated as many times as desired by the plant breeder. During the period of bulk propagation natural selection presumably plays a role in shifting gene frequencies towards the desirable genotypes and finally pure lines are developed by the pedigree method. Suneson and Wiebe (1942), Suneson and Stevens (1953) and Suneson (1956) studied the characteristics of varietal bulks and the bulks of hybrid generations and the progenies isolated from such bulks of barley. Harlan (1956) listed 20 varieties of barley which could be traced directly or by parentage to composite cross populations.

With both the methods viz. pedigree and bulk the end product was much different than the parental varieties since it combined large number of characteristics from the two parents. Sometimes breeders are confronted with a problem of improving an excellent variety precisely for one or two characteristics only, in which it is deficient. Back-cross method, therefore, aims at reconstituting the genotype of a particular variety with addition of a character or characters for which it was deficient. In this method series of back crosses are made to the variety to be improved during which the character in which improvement is sought is maintained by selection. At the end of the back crossing, selfing produces homozygocity for the character under transfer, and the selection results in a variety with exactly the adaptation,

yielding ability, and quality characteristics of the variety which need improvement but superior to it in the particular characteristic to which the improvement programme was undertaken. Harlan and Pope (1922) pointed out the possibility of the method in small grains and also Briggs in 1922 started an extensive back crossing programme to develop bunt-resistant varieties of wheat. Back cross method has been used extensively for breeding disease resistant varieties particularly to wheat rusts in Australia, North America and South America. Sometimes many wheat breeders did not use the full back cross technique to reconstitute the recurrent parent, but used only one, two or three back crosses so as to retain the benefits of transgressive segregation for agronomic characters such as yield and adaptation. The method has its own limitations and might serve a useful purpose in some situations and not in others.

Breeding cross-pollinated crops : Handling of variation and its mobilization for improvement in case of cross-pollinated crops differs considerably, due to the difference in the basic structure of the population in the two cases. Self fertilizing stable populations are essentially made up of different homozygous genotypes or of a single homozygous genotype in case of pure lines. In contrast, the cross-pollinating species are highly heterogeneous and carry high degree of heterozygosity which allows perpetuation of a large number of deleterious recessive genes as mutation load in the population. Fisher in 1930 pointed out that among out breeders natural selection alters the phenotypic expression of heterozygotes towards the phenotype of the most favourable homozygote, which results in dominance of one allele over another. It is a common observation that when such highly heterozygous populations are subjected to close breeding or inbreeding they deteriorate considerably due to homozygosis at various loci carrying undesirable recessives. Therefore, in all breeding programmes for cross-pollinated crops the objective is either to develop completely heterozygous genotypes at the end of the breeding programme or to maintain a high degree of heterozygocity during the breeding programme and in the final variety, an attempt is made to accumulate high frequency of desirable genes in the population. The former is achieved by breeding for hybrid varieties where F_1 generation of a cross or crosses is used for commercial cultivation, and for the latter different

forms of mass selection and recurrent selection programmes are followed which result in the development of synthetic and composite varieties.

Hybrid varieties : The concept of hybrid varieties was based on the phenomenon of heterosis exhibited by the F_1 hybrids between certain genotypes. The hybrids may be produced from inbred lines, clones, varieties or any stock which on crossing produces an F_1 superior to either of the parents. Beal in 1877 was first to report on yield data of varietal hybrids in maize and stated that the hybrids outyielded the parents. Shamel in 1905 (quoted from Smith, 1966), reported yields of two lines of corn, inbred for three generations and their hybrids. This was probably the first report on hybrids between inbred lines. Also East and Shull around 1904 and 1905 started extensive study of inbreeding and hybridization in corn which formed the basis of further study and exploitation of hybrid vigour in corn by Hayes, Jones, Kiesselbach, Wallace and Richey. Shull in 1909 suggested a pure-line method of corn breeding based on inbred lines obtained by continued selfing and the use of F_1 hybrid between these lines. The breeders working on maize hybrids soon realized that a hybrid between any two unrelated inbred lines of maize is certain to show at least some increase over its inbred parents, but production of superior hybrids depended on the combining ability of particular inbred lines in hybrid combination. Therefore, *development and evaluation of inbred lines in a standard* inbred hybrid approach became one of the most important activity, since very few of the thousands of inbreds which are developed show heterosis to a degree to make them economically valuable for hybrid production. Kiesselbach estimated in 1951 that of the more than 1,00,000 inbreds which had been tested, only 60 were good enough to have been used in the commercial production of hybrid maize. Several important and practical methods were developed to simplify the procedure of developing hybrid varieties. The method of convergent improvement in corn was proposed by Richey (1927) and was further described by Richey and Sprague (1931). Davis (1927) suggested the use of inbred variety cross for simplifying the testing corn inbreds and Jenkins and Brunson (1932) used this top cross method to give comparative tests of combining ability. Jenkins in (1934) also evaluated methods for predicting double cross performance

from the yields of component single crosses. Jenkins (1940) and Hull (1945) suggested the method of recurrent selection to improve the combining ability of inbred lines and in 1949 Comstock, Robinson and Harvey proposed the method of reciprocal recurrent selection, which is useful in selecting simultaneously for both general and specific combining abilities.

Inbred lines used for hybrid maize production simulated in many ways the pure lines of the self-pollinated crops and under certain situations these could be improved by using some of the methods well-known for self-pollinating crops, like pedigree and backcross methods.

Presently entire corn growing area in United States is grown with hybrid varieties, and due to this switchover from open-pollinated local varieties of maize to the hybrid varieties, there has been an increase of 20 per cent in the total maize production. The development and success of double cross maize hybrids not only revolutionised maize production in U.S.A. but had great impact all over the world. Also encouraged with potentialities of maize hybrids great deal of enthusiasm was shown by the breeders for exploiting the phenomenon of hybrid vigour in other crops and as a result, hybrid varieties were soon developed in sorghum, onion, tomatoes, sugar-beets. Recently in India most striking achievement has been made in increasing the yield of *bajra* (*Pennisetum typhoides*) to an extent of 100 per cent by the development of hybrid development of hybrid *bajra* No. 1. Efforts are being made by the wheat breeders to make hybrid wheat a reality.

In case of hybrid varieties F_1 seed is to be produced and distributed every time crop is planted and, therefore, production of hybrid seed forms an important part in the popularity and the practicability of these varieties. The discovery of cytoplasmic male sterility and its use by Jones and Davis (1944) in producing hybrid seed of onions has simplified the process of hybrid seed production considerably. In case of the species where cross-pollination through mechanical means was not possible on a large scale, production of hybrid seed was out of question until the possibilities of cytoplasmic male sterility were realized, even though the hybrid combinations between two strains showed

high degree of hybrid vigour, for example, sorghum, *bajra*, onions, carrots and sugar-beets. Kihara (cited by Briggle, 1963) reported the first cytoplasmic male sterility in wheat in 1951, when the nucleus of common wheat was observed to be influenced by the cytoplasm of *Aegilops caudata*. Commercial possibility of hybrid wheat seed received attention only when Schmidt *et al.* (1962) discovered pollen fertility restorers in a hexaploid derivative of *T. timopheeyi*. It is hoped that commercial cultivation of hybrid wheat, hybrid barley and hybrid cotton will become a practical proposition in the coming years.

Population improvement : Dobzhansky (1951) defined Mendelian population as 'a reproductive community of sexual and cross-fertilized individuals which share a common gene pool'. Therefore, a Mendelian population is the group of individuals mating randomly. In population of cross-pollinated crops the genes constitute a pool in the form of gametophytes which combine randomly to give next generation. The next sporophytic generation is never quite the same combination of genes. However, the gene pool is quite a stable entity, that produces genotypes performing on the average about the same from generation to generation. In stable populations the gene and genotype frequencies remain constant within the limits of random fluctuations. Changes in the frequencies of some genes or genotypes result in changes in others. Therefore, the changes towards high frequency of desirable genotypes in a population results in the increase of desirable genes in the gene pool, which attains new equillibrium and continues giving desirable genotypes in subsequent generations. This is the main basis of the programmes of population improvement.

Mass-selection has been the simplest method of increasing desirable genotypes in a cross-pollinated population. The American-Indians practised mass selection of corn for several centuries and as a result were successful in establishing all the available endosperm types like dent, flint, flour and sweet types. Although mass-selection has been quite effective in the beginning and was responsible for the maintenance of most of the open-pollinated varieties of maize, it was found not a very useful method in improving maize yields in the early years of the present century. The main reasons for failure of this method probably were :

1. Working with limited genetic variability;
2. Lack of adequate statistical techniques;
3. Lack of understanding about genetic phenomenon in the populations;
4. Striking results of hybrid vigour and the emphasis on the development of hybrid varieties only.

The results of recent work at several stations have created renewed interest in the method and has been found very useful where the material being handled is having a good deal of variability. The various forms of mass-selection used are (1) ear to row method, (2) phenotypic stratified mass-selection proposed by Gardner (1961) and (3) ear to row to ear breeding method a refinement of ear to row method suggested by Lonnquist (1964).

Besides mass-selection the different methods of recurrent selection also aim at population improvement through increasing the frequency of desirable genotypes based on to cross testing or some kind of progeny testing. Next generation of a population in all these cases is represented by the desirable combination of genes from the selected group of individuals, rather than from just one individual in case of selection under selfing or in segregating generations of a cross in self-pollinating species. If the selected population size is not very small the chance of random loss of favourable genes is reduced to minimum and inter-crossing between the selected individuals allows greater chance of recombination between favourable genes.

Recent studies by Gardner (1961) and Johnson (1963) have shown a gain of 5.5 per cent and 11 per cent, respectively per cycle of mass-selection for 3 to 4 cycles, while by recurrent selection procedure, Penny *et al.* (1963) reported a gain of 1.2 to 2.5 per cent per cycle only.

The results obtained here have encouraged the breeders to use these methods of population improvement even in self-pollinated crops. Andrus (1963) suggested (a) Crossing of superior selections in early generations, and (b) crossing of selections at random in early generations. These modifications impose on the population, the breeding system of cross-pollinated crops and, therefore, it is essential that a system of random mating among the selects be introduced through the

utilization of male sterility in self-pollinated crops like barley and wheat as suggested by Suneson and Wiebe (1962) and Athwal and Borlaug (1968).

Biometrical approach : All the methods discussed so far were highly effective in manipulating simply inherited characters, and rapid changes in the varieties of crops have been achieved with regard to major qualitative characters. However, when natural variability for quantitative characters like yield becomes limited, it is difficult to recognise and manipulate this limited variability for these characters by ordinary methods.

At first place it took a long time to understand the genetic nature of non-discrete continuous type of quantitative variation. Yule in 1906 was first to suggest that there was no conflict between particulate inheritance and continuous inheritance if many genes having small and similar effects were postulated. Also about the same time Johannsen demonstrated that seed weight in beans varied continuously as a result of heritable and non-heritable factors. Finally, East in 1916 provided conclusive evidence for inheritance of quantitative characters on the basis of a number of segregating genes with similar effects, from his experiment on corolla length in tobacco. Soon it was recognised that the main difference between quantitative and qualitative characters is in the magnitude of single gene effects relative to environmental effects. According to Mather the genes for quantitative characters are 'the genes of smooth adaptive change and the genes of fine adjustment'. The difficulty in manipulating these genes is due to greater complexity in mode of inheritance and the environmental effects.

The general aim of quantitative genetics is to find out, how the observed properties of the population viz., means and variances and covariances are influenced by the properties of genes and by the various non-genetic factors. On one side it seeks to partition the variances in the genetic and non-genetic components and on the other it makes an attempt to understand the nature and action of genes and the systems into which these genes are organised, since improvement in genotypes under selection depends on the rate at which combinations of superior genes can be put together

which in turn depends upon the systems into which the genes available to the breeder are organised. In this field the main concepts which have increased the precess of predicting the outcome of selection in a particular population and have influenced the breeding methodology are :

1. Concept of heritability and genetic advance;
2. Genotype environment interaction;
3. Variance component analysis and estimation of gene action;
4. Discriminant functions and use of selection indices.

Variance components and determination of the type of gene action involved in a particular population is of great significance with regard to the efficiency of breeding methodology followed in a particular population. Cockerham (1961) stated that "all the systems of selection are fruitful if gene action is entirely additive. With little doubt, however, the proper combination of mass, family and progeny test selection would the most effective. With the inclusion of dominance, the picture is not as clear because the degree of dominance is important. If a substantial number of loci exhibit overdominance, then it is imperative to use a scheme which will lead to a heterozygous genotype. With partial-to-complete dominance the most efficient method is not easily pinpointed. The inclusion of epistasis makes the picture even less clear. Epistatic gene action can be very complex. All methods of selection would be effective for certain types of epistasis. Mass and family selection, for example, can make some kinds of additive types of epistasis, but it will be ineffective with others". Investigations in self-pollinated and in cross-pollinated crops have shown predominance of additive genetic variance and, therefore, the development of hybrid varieties as the best method for increasing yield is being questioned seriously by various workers (Matzinger, 1963; Wellhausen, 1965; Centz, 1966 and Sprague, 1966).

However, uptill now very little use of biometrical approach has been made in applied plant breeding programmes. Most of the techniques have been regarded as an end in themselves, rather than a means to an end. Nevertheless it is being recognised that as soon as the progress from conventional methods is difficult, the biometrical techniques may become

the powerful tool in the hands of plant breeders for making further improvement in the yield of crop varieties.

Cytogenetical approach : Cytogenetics deals with the organisation of the genes on chromosomes and, therefore, creation of desirable variants by cytogenetical techniques takes place at the chromosomal level as well as at the genic level. The manipulations at chromosomal level include autoploidy, aneuploidy, alloplyploidy from interspecific crosses and structural changes. At the genic level the changes relate to mutations.

Use of ploidy : The change in the basic genomic chromosome number sometimes increases the utility of a crop. Both increases and reductions in ploidy have been exploited, though reductions have been studied to a very limited extent and may be useful as a means to come over certain specific breeding problems. The use of colchicine after the investigations of Blakeslee (1937) permitted the production of the vast number of polyploids in the past 30 years. The most useful have been autotetraploid rye, seedless autotriploid watermelon and autopolyploid sugar-beet; autotetraploid berseem, triploid apples and grapes. Autopolyploidy has been quite useful in case of crops where vegetative parts are mainly used and in a sexually propagated species, where high sterility of autotetraploids does not become a problem Gilles and Randolph (1951), Swaminathan and Sulbha (1959), Smith (1960) and Hilpart reported that selection for fertility within autotetraploid lines improved plant fertility considerably. Also diploidization of tetraploids by inducting structural differences has been suggested.

Use of allopolyploids resulting from the dulpication of different genomes of the two different parental species have been of less success than induced autopolyploids. The most quoted example is of triticale which combines the genomes of *T. aestivum* and *Secale cereale.* Recently Muntzing (1963) and Pissarev (1963) have reported availability of trilicale lines in which the defect of low fertility and poor quality has been removed. Sears (1956) used induced allopolyploid between *Aegilops umbellulata* and *T. dicoccooides* as intermediary bridging form in the transfer of leaf rust resistance from *Aegilops umbellulata* to common wheat.

Chase (1949) outlined the use of monoploids to derive homozygous diploids in corn to save time. Hougas and Peloquin (1958) discussed the use of potato haploids in breeding programmes, and recently based on the similar ideas Chase (1964) proposed analytical method of breeding allopolyploid crops. Riley (1963) pointed out that certain clear benefits could result from the use of haploidy in breeding crops. For example, if it was possible to induce the F_1 plants of intervarietal crosses to set seeds with haploid embryos parthenogentically, the first products of segregation and recombination could be isolated. With colchicine these could be made diploid and homozygous, so heterozygous generations are eliminated, which normally intervene between the first hybridization and release of a new variety. He pointed out that in the wheat variety Hold fast monosomics for chromosome I produce a very high frequency of haploids—28 in total of 80 plants. If pollen of this material permits the development of haploid embryos but normal endosperm, then this stock could be used to pollinate heterozygotes, and haploidy could be used in wheat improvement and a new cytogenetic system of breeding developed. Recently Niroo Niizeki and Kiyoharu Oon (1968) were successful in inducing haploid rice plants in other cultures. If techniques are developed by which large number of haploid plants are obtained from the F_1 hybrids it may prove a very useful tool particularly in situations where due to certain linkages it is not possible to recover the combinations which show very promising performance in the early segregating generations, that is, in F_1 and F_2, but get diluted in advanced generations and may never be picked up.

Use of alien genetic variation and chromosomal structural changes : Work on wheat and tobacco has shown that it is possible to utilize alien genetic variation even if recombination between the two different parental species through meiotic pairing is not possible by the development of alien addition lines or alien substitution lines. However, the lines having full chromosome pair substitution or addition suffered from disadvantages such as low fertility, cytological instability, disturbances in quality and, therefore, could not be of much applied use. To overcome these difficulties Sears (1956) demonstrated the use of induced translocations to introduce small chromosome segment of *Ae. umbellulata* carrying a gene for leaf rust resistance into wheat chromo-

some. Following Sears technique Knott (1961) Driscoll and Jensen (1963), Sharma and Knott (1966) and Wienhues (1966) obtained several translocations from *A. elongatum* and *Secale cereale* into wheat for resistance to stem rust and leaf rust. Sharma (1968) reported the cytogenetical behaviour of such translocation. Riley (1963) suggested the use of nulli V in wheat to get allosyndetic recombinants in species crosses. Also multiple translocations have been used to produce seedless watermelon by Japanese workers (Oka *at al.* 1967).

Besides the use of translocations to get new recombinations Burnham (1962, 1966) has given details about the use of interchanges and duplications as cytogenetic tools in plant breeding. Duplications could have definite use in case of dose effect of beneficial alleles as in case of genes with high amylose activity in barley. Also the allele V for two row Reads in barley interacts favourably with the allele v for six-row in heterozygotes. By combining V and v on the same chromosome it would be possible to have a pure line of genotype VVvv, which presumably would exhibit the vigour of the genotype Vv. Such techniques may open up entirely new possibilities in plant breeding as stated by Riley (1963) 'it is clear that the increasing sophistication of cytogenetic method has improved its practical potentialities, for in the control which it gives in the synthesis of the improbable genotypes required by the plant breeder, the engineering approach of cytogenetics is unexcelled !

Mutation breeding : De Vries in the beginning of the 20th century stated that 'the knowledge of the laws of mutations will presumably lead to the induction of artificial and international mutations and so produce entirely new characters in plants and animals. In future it may even be possible to create better species of cultivated plants and domestic animals by the control of mutations. However, the use of induced mutations in plant breeding received due attention only after 1927 and 1928, when Muller in Drosophila and Stadler in plants convincingly demonstrated artificial induction of mutations by ionizing radiations. During the period of last 40 years tremendous amount of information has been accumulated on the basic issues of radiation effects on hereditary material, and besides radiations some very potent chemical mutagens have been discovered. The detailed

achievements in this field have been reviewed extensively by Mackey (1956), Prakken (1959), Gaul (1961, 1963), Gregory (1961, 1966), Gustafsson (1963) and Swaminathan (1965a, 1965b). The results obtained by various workers indicate that artificial induction of mutations has appeared as one of the very important tools in the hands of the plant breeders, which under certain situations could be used with great efficiency. Awned mutant in the wheat variety N.P. 836, dwarf mutant in N.P. 824 and a mutant for jassid resistance in the susceptible cotton variety Mescialla Acala, (Swaminathan, 1965) and induction of highly desirable amber grain colour in the Mexican wheat variety Sonora 64 by Verughese and Swaminathan (1966) are some of the glaring examples of removing a specific genetic defect through radiation induced mutations. Recently Sharma (1968) stressed the raputic use of radiations in overcoming genetic defects like hybrid necrosis in wheat (Sharma, 1968) and pointed out that manipulation of genetic factors through the use of mutagenetic agents is a very useful technique for overcoming the limitations set by certain genetic situations. For example, Saini and Sharma (1969) reported success in breaking the pleiotrospic complex in rice and were able to recover new recombinations with desirable plant height and response to high fertility of Taichung Native-I and the grain type of a local tall variety Jhona-349 by irradiating the F_2 seeds of a cross between them, when no such recombinants were found in untreated segregating population.

The extent to which breeders may use induced mutations as a tool in plant breeding depends on thorough understanding of the particular genetic situation breeder is confronted with, and on the efficiency of mutation induction. In general mutation breeding may be most profitably used in breaking definite genetic barriers, recovering difficult recombinations, inducing male sterility and affecting gene transfer for such characters as disease resistance.

Concept of efficient plant type : Maximum production per unit area is the need of the day due to the tremendous increase in world population. However, it has been realised by the breeders world over that most of the varieties which were bred for normally low fertility level during extensive agriculture days, do not stand high fertility conditions, and tend to lodge when given high doses of fertilizer and frequent

irrigation, particularly at the time of milk stage when heads become quite heavy. Therefore, for maximum utilization of both fertilizer and water it became essential to develop new type of plant with short culm.

The discovery of a single dwarfing gene in some indica varieties of rice from Taiwan and dwarfing genes of the wheat variety 'Norin' from Japan proved very useful in the development of varieties like Taichung Native-I, IR-8 of rice and P.V. 18, S-227 and Sonora 64, of wheat which proved a major breakthrough in rice and wheat yields.

Utilization of dwarfing genes in rice and wheat for getting response to high fertility is only one of the many aspects of manipulating the plant type. The physiological work on rice has shown that the most desirable plant characteristics would be shorter height, and short, dark green erect leaves, which avoid mutual shading (Beachel and Jennings, 1965). In maize Pendleton *et al.* (1968) reported that a backcross derived isogenic single cross hybrid carrying Jg_2 gene for erect leaf produced 40 per cent more grain than its counter part with normal (horizontal) type leaf. The photosynthesis measurements on individual corn leaves showed the relative efficiency of Co_2 fixation per unit of sunlight to steadily increase as the leaf angle decreased.

Izhar and Wallace (1967) showed that a genetic mechanism is responsible for large differences in photosynthetic efficiency as shown by net Co_2 exchange rate. Also genetic differences have been found with regard to uptake of phosphorus, zinc and potash in maize (Gorsline *et al.* 1961 and Thomas, 1963). This indicates that there may be types which are more efficient in nutrient absorption through roots and might have better canalized metabolic system resulting in better growth and development.

In the light of the above facts the future plant breeder might have to look for physiologically efficient plants on one hand, and on the other for a plant type whicn is most efficient in utilizing sun light and Co_2.

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Quantitative Genetics for Plant and Animal Improvement

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Quantitative genetics deals with the inheritance of quantitative characters which show continuous variation and can be measured in metric terms. An understanding of such variation is important in the study of evolution and the application of genetics to plant and animal improvement. The familiar Mendelian ratios, which display the fundamental mechanism of inheritance can be recognised when a gene difference at a single locus gives rise to a readily detectable difference in some property of the organism. Continuous variation depends on gene differences at many loci, the effects of which are not individually distinguishable and hence the Mendelian ratios are not exhibited by quantitative traits. This necessitates the study of populations or groups of progenies and measurements are made on individuals rather than by classification into groups. Quantitative genetics enables us to describe the properties of a natural or experimental population and to predict on the applicability of a breeding plan, which would enable a study of properties of the genes concerned.

Galton (1889) tried unsuccessfully to establish the inheritance theory by studying human data with small families and uncertain ancestry and further choice of metric traits like stature in man were responsible for his failure in establishing the laws of inheritance. Mendel deliberately neglected such variation in his experiments, presumably with the clear recognition that it would only have a distracting influence on his analysis. Development of pure line theory by Johnson

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(1909) and multiple factor hypothesis by Nilsson-Ehle (1909) have made significant contribution in the development of quantitative genetics. Johnson with his experiments on beans showed that both hereditary and environmental factors influenced the variation in seed weight and only a breeding test could distinguish between their affects on the phenotype. Nilsson-Ehle found in wheat and oats that more than one gene with similar effects could affect the inheritance of grain colour and the intensity of colour depended on the number of dominant genes present. Nilsson-Ehle and East independently realized that similar factors of smaller individual effects could account for continuous variation if enough of them were segregated, as the phenotypic expression would depend on factor dosage and variation would be quantitative following Galton's frequency curves. The continuity of the phenotypic variation is smoothened by the influence of the environmental agencies. Fisher showed that inheritance of a number of continuously variable characters in tobacco and maize could be fully accounted for on this view. Fisher (1918) attempted the first partitioning of continuous variation into the components expected on multiple factor hypothesis.

While East (1915) observed parallelism between Mendelian segregation and segregation of quantitative traits. Sax (1923), Rasmksson (1935) and Mather (1942) provided evidence for nuclear inheritance of quantitative variation by studying linkage between polygenes and major genes and also between groups of polygenes. Polygenes (1943) differ from major genes in that they occur in systems, the members of which have small, similar and supplementary effects. They are genes of fine adjustment clothing the indispensable skeleton of major genes and moulding the whole into a fine shape demanded by natural selection. They are genes of smooth adaptive changes—the root cause of speciation.

Variation in one character may be caused by alteration in any one of a number of genes governing that character and just as one gene may differentiate two strains, two different genotypes may show the same phenotype. Such differences are widespread and of great importance in evolution (Harland, 1936). Also, one gene may influence more than one character. The complexity of gene's pleotropic effects is traceable to a single initial action, which changes the general course of development and leads to the gene change expressing itself

in a syndrome of varied abnormalities. The longer the chain of gene action, the more complex are its effects on phenotypic expression. Multiplicity of stages between initial action and final expression offers opportunities for the character to be changed by other genes and by external agencies. This would hold good even if, as Beadle (1945) suggests, a single primary action is characteristics of a gene. The complexity is greater when gene has more than one primary action and the same primary action can be shared by a number of genes, as in the case of polygenes. Perhaps the concept can be well-understood on the one gene—one polypeptide theory based on the hypothesis of Jacob and Monod (1963).

The genetic analysis is limited by the complexity of the relation between a gene and a character. A breeder cannot choose genes with which he will work and is concerned with all those contributing to variation in a character. Genetic analysis may be simplified by a prior phenotypic analysis. The phenotypic variance may be partitioned into genetic and environmental components by using an efficient experimental design, that may be extended over a number of years and locations as the same genotype may not give the same phenotypic expression in all the environments. Location and seasonal differences are insensitive measures of the interplay of genetic and environmental factors, whereas different conditions of soil moisture, fertility, temperature, etc., are sharper and more pertinent measures. A less variable phenotype is considered homeostatic and this phenotypic stability is desirable and simplifies the breeding procedures.

In a breeding programme, knowledge of genetic variance (Vg) is important because if we take top q per cent of a random sample of n progenies we generate, the selection being made on the basis of observed means of the n varieties, subject to a variance (Ve), then the difference between the true mean of the selected percent and the mean of the whole population is $K.Vg/\sqrt{Vp}$ when $Vp = Vg + Ve$ and k depends on q and n (Yates 1938, Lush, 1946). We can now say whether it is worthwhile to make selections for high-yielding lines. In a single factor mating designs, where all the progenies are descendants of the same parental material, genetic variance is an estimate of genotypic differences between the lines. In two factor mating designs

(top cross and diallel cross) one can ascribed the genetic variance as arising from combining ability of the parents and the cross combination and the reciprocal effects which in a diallel cross can be partitioned into material effects and residual discrepancy in reciprocal crosses. The three factor (triallel cross) and four factor (quadrallel cross) mating designs, provide additional information on the contribution of grand parents and the combining ability of three-way and double crosses. The concept of combining ability is of much importance in animal and plant breeding. According to Sprague and Tatum (1942) general combining ability designates the average performance of a line in hybrid combinations while specific combining ability is used to designate those cases in which certain combination do relatively better or worse than expected on the average performance of their parents. The general combining ability accounts for additive gene effects and is more important in previously unselected lines but when dealing with a group of selected lines or inbreds, specific combining ability is more important and dominance and epistasis are largely responsible for its expression.

Many characters like yield are made up of several sub-characters, each of which may be under separate genetic control and simpler in inheritance. However, some genes may effect both or any pair of sub-characters and the variation of the two may be correlated, the degree of correlation depending upon the genes causing such variation, their developmental relations and their linkage. Correlation is the inter-relationship of two variables and since all the genes effecting the phenotype of two variates may not be the same or may not be completely linked, the correlation is seldom complete and must be tested for its significance to confirm if the observed correlation is real or by chance. Covariation of a pair of characters may also be due to the influence of a common third, and the partial correlation measures the association of two variates after allowing for their correlation with a common third. The dependance of one variate on the other is termed regression and if b be the regression of Y on x, the relationship between two characters can be expressed by $Y = \overline{y} + b(x - \overline{x})$. By using this relationship we can select for Y on the performance of X. We can also know the variation in Y accounted for by variation in X and thus compare the efficiency of the selection indices. This relationship can

further be extended to a number of components which are related to a complex character by making use of the partial and multiple regression.

Just as a character may be capable of resolution into a number sub-characters, it may itself be one of a number of characters in whose joint properties we are interested and which together form a super-character. For example, yield, quality, disease resistance etc. form a super-character as the overall merit of a plant. The relationship between a character and a super-character is generally not capable of measurement and definition. A generally applicable way of combining characters in a single character is the use of Fisher's (1936). Discriminant Functions which resemble multiple regression equations and can be used whenever it is possible to represent our needs in the form of a maximization of differences between recognizable classes. First use of Discribminant Function in plant selection was made by Smith (1936) and in animals by Hazel (1943). A number of its uses range from anthropometric classification of skulls to parent selection in plant breeding, but the most common use is in the handling of taxonomic data for classification into species. In plant breeding, the general problem is to select for high values of a complex character, like yields on the basis of its components in such a way that there is maximum concentration of genes for high yield in the selection made. This is achieved by maximizing the regression of phenotype on the genotype.

Genetic variance can be partitioned into additive and non-additive components. Additive variance is fixable but non-additive effects, considered unfixable by Mather (1949), are in part heritable and thus fixable (Comstock, Robinson and Harvey 1955; Hayman and Mather 1955 and Hayman, 1958). Fisher, Immer and Tedin (1932) developed a method of determining the contribution of each gene to the above components of variance. If $\pm$d measures the deviation of a parent from mid-parent value and h the deviation of F, the variance in segregating generations can be described in terms of $X=Sd^2$, the additive and $H=Sh^2$, non-additive components. The ratio h/d measures the degree of dominance (Potence ratio) and is based if genes are not isodirectionally distributed and if all the h increments have not the same sign; but D and H provide a better estimate for the

degree of dominance.

Observed variance for which diffrence in heredity is responsible, is called heritability (Knight 1948). In broad sense, heritability considers all the genes variance while in narrow sense it is the additive part of it in relation to total phenotypic variance. In selection of individual animals, sampling is not involved and heritability in strict sense is an acceptable definition which relates it to selection concepts. For quantitative measures in plant breeding, a plant, a field plot, replicated field plots in one or more environments may be considered as a reference unit and each reference unit will affect the definition of heritability. Heritability has value primarily in quantifying the concept of whether progress from selection is relatively easy or difficult to make in a breeding programme. If additive variance is high reliance should be mainly on mass selection; if epistasis is high selection between families and line breeding be resorted to; if over-dominance is operative emphasis should be on development of F_1 hybrids for commercial use, and if genotype—environment interaction is high, the breeder should aim at developing separate variety for each ecological region (Lush 1948). Lush (1940, 49) has provided methods of estimating heritability. In animals parent off-spring relationship has been commonly used. In plant breeding partioning of variance into genetic and environmental components through experimental designs is helpful in estimating heritability in the broad sense and partioning of genetic variance in additive and non-additive components provides estimate of heritability in both the broad and narrow sense. Regression of off-spring on the parent provides an idea of heritability in the strict sense but dominance and genotype-environment interaction can seriously bias this estimate. Horner (1957) has suggested an estimate of heritability in standardized units which is equal to using the correlation coefficient instead of regression coefficient.

The speed of selective advance depends on the number of units of inheritance. With a large number of genes involved, the chance of immediate fixation of extreme homozygotes, through selection is remote and progress is incomplete as the extreme homozygotes form a large portion of segregates. The speed of selective progress depends on the rigour of selection number of groups of polygenes, additive

gene effects, dominance epistasis, linkage, environmental and sampling variance.

Linkage does not affect the frequency with which allelomorphs of each gene are recovered in segregating generations. It only affects the frequency of particular combinations. It, therefore, will have no effect on mean measurements but will affect the variance. Test on linkage is the test of homogeneity of D and H in successive generations.

Many workers have stressed the importance of genic interactions usually termed as epistatis effects apart from additive and dominance effects (Wright, 1935; Sprague and Miller, 1950; Grafius, Nelson and Diaks, 1952; Anderson, 1954 and Anderson and Kemthorne, 1954). Hayman and Mather (1955) proposed four interaction parameters as i, the additive×additive interaction, j, the additive×dominance interaction and l the dominance×dominance interaction, and all the classical digenic interactions could be fixed on these terms. Horner, Comstock and Robinson (1955), derived expectations of genotypic means, variances and covariances, assuming the operation of epistasis and observed serious bias due to epistasis on estimates of average dominance, additive and dominance variance. Jones (1958) partitioned heterosis in four components expressing the role of additivity, dominance, epistasis and linkage. Hayman (1958) worked out expectations of progeny means on the basis of d, h, i, j and l components. Grafins (1959) emphasised the importance of epistasis in self-pollinated crops and mentioned that contrary to heterosis due to heterozygosity, the F_1 vigour due to interaction of additive quantities is fixable in true breeding forms. The most practical use of epistasis has been demonstrated by Joshi and his coworkers in linseed. Gupta (1958-61) observed that interaction effects were higher for yield than the additive gene effects, while the reverse was true in yield components. Some of the heterosis observed in F_1 was retained in F_2 and transgressive segregates were observed for characters showing complementary epistasis. Magnitude of transgressive segregation was associated with additive×additive interaction, and this part of heterosis was found to be fixable even in F_3 generation. Progenies in F_3 of different crosses performed according to the predictions made from the F_1 and F_2 analysis (Bhatnagar 1962). Most of these progenies have now resulted in promising strains.

Multiple allelism poses a complicated problem and no explanation of its effect is available. In the study of linseed referred above, only a gene model based on duplicate epistasis, linkage between dominant genes and multiple allelism of genes for earliness and lateness could explain the F_2 segregations for days to first flowering.

In the randomly mating population, genetic variance can be partitioned without using the parents or F_1. The use of correlation between relatives to analyse such populations is based on the fact that when a correlation r exists between two variates, r^2 is the proportion of variation, in one variate accounted for by variation in the other, leaving $1-r^2$ as residual variation for which causes must be sought. The degree of resemblance between relatives provides means of estimating the additive variance and an understanding of its causes is fundamental to the practical study of metric characters and to its application in plant and animal improvement. The covariance between relatives can be explained in terms of additive (V_A), dominance (V_D) and epistatic (V_{AA}, V_{AD}, V_{DD}) variance (Kempthorne 1955). Additional covariance due to linkage appears with the interaction components (Kempthorne 1956) and, therefore, variance due to epistasis may in part be due to linkage. The covariance is generally not influenced by the environmental component. Genetic variance in a random mating population is of the same magnitude as the F_2 variance in a single cross and can be explained in terms of $D=Sd^2$ and $H=Sh^2$ only if the frequency of dominant and recessive genes is equal. Fisher (1918) used this concept for analysing human data. However, if random mating cannot be fully justified marital correlations will have some effect and also the genotype-environment interaction may play an important role.

One experimental design which avoids at least the influence of marital correlations is that of diallel mating. This method is a powerful method of obtaining a rapid overall picture of genetical structure of a number of parental lines. This method obtains sufficient information from grouping of crosses from a diallel set into arrays rather than by using large families of one cross. Besides the usual information on variance components and the combining ability of parents and their off-springs, this analysis provides information on average additive gene effects, heterozygosity, dominance

relationships of the parents, degree of dominance, epistatic effects, relative gene frequencies and number of effective factors. If epistasis is operative, its causes can be determined and in its absence bias due to linkage can be ascertained. Determination of heterosis and its causes puts the diallel analysis into much importance as it is essential to gain some idea of the genetical structure of heterosis which is of great importance as a means of increasing the yield of plants and animals. The triallel and the quadrallel analysis are extension of the diallel analysis to all possible three way and all possible double crosses from a single group of individuals.

Different mating systems have extensively been used to know the breeding behaviour of a number of parents, the size of the population studied being dependent on the system followed. However, in such studies when large number of crosses have to be made and studied, limitations of resources and even the models of analysis, do not encourage a study of very large number of lines. The recently developed concept of Vector analysis is of considerable importance in that we can study a large number of lines, no crosses are made and breeding behaviour of the parents is predicted without growing the F_1 or successive generations. One can predict whether to make single crosses, back crosses, double crosses, triple crosses or synthetics and what proportions of different parents be combined. In this analysis a large number of triats are handled simultaneously and the entire genotype is described by a Vector, the relationship between two Vectors being $r = \cos Q$ when r is the correlation between two sets of data and r^2 measures the degree of determination of one set by the other.

In the end I may say that mathematics, the basic tool of the quantitative geneticist, offers great promise for its application to biological problems and many developments are yet to come from these applications. The quantitative geneticist with competence and interest in biochemical, physiological and ecological genetics may play an important role and as we have been able to explain evolutionary changes in the past, it may be possible to predict future changes in organisms. The breeders have been quick to realize the impact of Mendelism and the ever expanding science of genetics in plant and animal improvement. Progress has equally depended on the improvement in field plot techniques

and experimental statistics. Still, the present situation is that there is a wide gap between theory and practice and much experimentation is needed to test the usefulness of the biometrical methods. Though present day knowledge of quantitative genetics is not completely adequate to answer all the important breeding problems yet a considerable body of theory is available which must be used adequately by the breeders. Progress in plant and animal improvement will depend upon the genetic information and extent to which it can be utilized.

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Plant and Crop Improvement through Interspecific Hybridization

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Interspecific and intergeneric hybridization is the crossing of plants belonging to different species or genera in other words, the crossing of plants belonging to reproductively isolated species. Although several of our field crops are polyploid in origin and developed by the combination of several related species, the role of wide crosses have not been fully realised. However, it is apparent that under favourable environmental conditions, these can enhance some phases of evolution. The interspecific hybridization procedure has been followed by the plant breeder on an empirical basis a long time before the concept of the modern plant breeding methods were fully-realised. Although it is now an important breeding method, its value varies depending upon the plants under cultivation, the use to which they are put and the environmental conditions under which they grow. This fact can be ascertained by reviewing the progress of work which has been achieved in different kinds of crops.

Interspecific hybridization has played a most important role in ornamental plants such as roses, tulips, pansies, orchids, chrysanthemum and dahlias. Hybridization in most of these cases was not only restricted to related species but even between different genera. It has been next in importance in orchard crops, i.e., apples, plums, cherries, grapes etc. Its role has been less important in the forage crops, and least important in most of the field crop, viz., cereals, fibre

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and oilseed crops. In recent years, the role of interspecific hybridization has been quite important and this has been achieved through the transfer of specific genes.

According to Stebbins (1950), the importance of interspecific hybridization between these classes of crops can be explained on the basis of two assumptions : that interspecific hybridization has been of greater value first, for the vegetatively propagated crops than those produced by seed and secondly, where the specific qualities of the produce are of greater importance than the total yield. Thus interspecific hybridization has been more important for those ornamental and orchard crops which are propagated exclusively by vegetative means, i.e., cutting and grafts etc., where any good hybrid once obtained could become the progenator of the new variety. However, in case of ornamentals, the quality or novelty is of greater importance. In field crops, most often both quality and quantity are important. Thus, the research worker cannot afford to change the crop completely by introducing a large number of genes from other sources.

The most serious difficulty which is encountered in interspecific hybridization is the development of barriers in crossing because of reproductive isolation. In several cases the pollen may not germinate on the stigma or the pollen tube and may not be able to penetrate the stigmatic tissue. In plums the stigma is receptive but there is a definite layer in the style which inhibits the growth of the pollen tube. In other cases the pollen tube has been found to burst in the style i.e. *Primula sinesia* and *Solanum nigrum* or it may travel so slowly as in apple and tobacco that the ovule may degenerate by the time the tube reaches there. In a few cases, the pollen tube may fail to penetrate the ovule.

Renner (1929) and Muntzing (1930) distinguished two types of sterility which they termed 'haplontic' and 'diplontic'. Haplontic sterility which is common in plants acts on the gametes or gametophytes and is not associated with any disturbance during the development of the hybrids. This is quite common in *Primula*, *Agropyron*, *Trifolium* and *Oryza*. The sterility in these cases may be due to cryptic structural differences. Diplontic sterility on the other hand is more common in animals than plants, and is due to either

genic or chromosomal differences. The disturbance in miosis may be (a) by failure of pairing of chromosomes, (b) asynapsis or desynapsis or by (c) lack of synchoronization at anaphase I or later stage.

Hybrid inability or weakness is quite common and follows after the parental gametes have united. These mechanisms act at various stages of growth of the hybrid from the beginning of the development of zygote up to the final differentiation of the reproductive organs. The growth and development of the hybrid may be totally stopped or inhibited to a great extent before reaching maturity. There may be several reasons which are responsible for the weakness or death of the hybrids. The first and the most important is the disharmony existing between the chromosomes and genes of the parental species. In animals, this kind of disharmony becomes evident in the first cleavage division. In plants, usually no abnormality is noticed in early miotic division but the failure usually coincides with the critical or maximal period of differentiation. McCray (1933) noticed the break-down of interspecific hybrids in *Nicotiana* at (a) 4-8 cell stage (b) differentiation of vegetative growing point and (c) stage of seed germination. The second reason of hybrid weakness is the incompatibility existing between the chromosomes or genes of one parent with the cytoplasm of the other. In such crosses, marked reciprocal differences may exist in the success of hybrids. Michaelis (1954) reported his work on *Epilobium* involving a cross between *E. hirsutum* × *E. luteum* where the F_1 was abnormal and abortive. However, in the reciprocal cross, the hybrid remained normal and fertile even when the whole nucleus was changed by repeated back crossing. The third reason of the failure of the hybrids may be due to the incompatibility between embryo and surrounding tissue which has been termed as *somatoplatic* sterility by Brink and Cooper. Although the hybrid grows normally and is quite vigorous, the hybrid does not get nourishment because of the failure of the endosperm, and collapses after a few days. This has been noticed in *Linum* and *Datura*. The presence of disharmony in the endosperm and not in the embryo is probably due to the presence of two sets of the maternal chromosomes in the endosperm against one paternal. It appears that interaction between endosperm and maternal tissue is more important than between endosperm and embryo.

Some of the barriers and difficulties mentioned above can be overcome by the outstanding techniques developed and employed by different research workers. The absence of miotic pairing between the chromosomes of the parental species will inhibit any recombination or transfer of genes. This difficulty can be overcome by the addition of a pair of alien chromosomes. Because of unstable conditions such as low fertility and poor quality of the hybrids with additional chromosomes, this method has not been very useful. However, substituting the alien chromosomes for a pair of recipient species removes several disadvantages cited above. Chromosome substitution has been made in the case of a rye chromosome for that of wheat and chromosomes from *N. glutinose* and *N. plumbaginifolia* for those of *N. tabacum*. Gene transfer can also occur by translocation between non-homologous chromosomes, which have been achieved in the transfer of genes for disease resistance from *A. umbellulata* and *Agropyron elongatum* to common wheat.

One of the major reasons in hybrid sterility is the non-germination of pollen grain and the difficulty in penetration of the pollen tube through the stigmatic layer. The presence of the stigmatic fluid may inhibit the germination of pollen grain. In some cases it has been overcome by growing the pollen in sugar solution before their application. In the case of *Gossypium herbaceum* × *G. hirsutum*, successful results can be achieved by treating the stigma with a dilute solution of sugarcane and citric acid prior to pollination. Increases of interspecific hybrids in certain millets and sorghum, the application of fresh stigmatic extract from the pollen parent helped in the germination of pollen grains.

The application of hormones and other chemicals has been used to overcome the barriers encountered in the normal process of fertilization. Grane and Marks (1952) were able to obtain a hybrid between pear and apple following the application of naphthoxyacetic acid at a concentration of 40 ppm. to the ovary and base of style. The hormone increased the growth rate of the pollen tube of the apple and in the style of pear, thus preventing the formation of an abscission layer. Some of the interspecific crosses in *Lilium* could be obtained only with the use of 1 per cent naphthalene acetamids in linoline to the ovaries and pistles. Species crosses in genus *Trifolium* and crosses between wheat

and rye could be successfully achieved by grafting.

In a great number of cases, the hybrids are completely male sterile but may set few seeds if pollinated by normal pollen from the parental species. Continuous backcrossing has been found to restore fertility to a great extent. In certain wide crosses in wheat and tobacco where there was no pairing and the hybrids were completely sterile, doubling of the chromosomes restored fertility considerably. In somatoplastic sterility which is due to incompatibility between the embryo and the surrounding tissue, the hybrids can be obtained if the young embryo is dissected at an early stage and grown in *vitro*. This has been reported, among others, by Laiback (1925) in *Linum*, Blackslee (1945) in Datura, Mangesdorf and Reeves (1938) and Anand and Leng (1963) in crosses of maize with *Tripsacum*, and by Skirm in a cross of *Prunus* and *Lilium*.

As mentioned earlier, interspecific hybridization has played a major role in the improvement of ornamental plants. Most of our present day varieties of flowering plants which can be propagated by vegetative means were evolved by this method. One of the noteworthy achievements which may be cited is the production of a triploid variety 'Gladiator' of canna, which was evolved by crossing a diploid and tetraploid species. As it was sterile, the flowers instead of setting seed, dropped at maturity and gave way to new blossoms. Work done in chrysanthemum, lily, snapdragon, dahlia and gladiolus has resulted in the production of a great variety of flowers within each. Although in most of the interspecific crosses, the hybrids are intermediate between the two species but in a few cases a radically different type can emerge by recombinations. Lotsy (1915) obtained strikingly exceptional off-types in the progeny of the cross between *Antirrhinum glutinosum* and *A. majus*. Similar results have been observed in *Poenia lactiflora* and *P. anomala*.

In fruit trees, wide crosses have resulted in the transfer of some of the desirable characters between species. In pears, the hybrid of *Pyrus communis* with *P. ussuriensis* proved more vigorous and much more winter hardy than common pears. The transfer of blight resistance from *P. serotina* and *P. calleryana* has also been found useful in the breeding programme. Interspecific crosses between the

old world and new world grapes have contributed to a great extent in the improvement of size, quality and yield of grapes. Cross of citrus with *Poncirus* and *Fortunella* have given interesting results for genetic studies.

One of the important contributions of interspecific and intergeneric hybridization in field crop improvement is the transfer of disease resistance to commercial crops from their wild relatives. This has been done effectively in wheat, tobacco, sugarcane, sugar-beet, and straw-berries etc. In cultivated species of tobacco the resistance to tobacco mosaic virus (TMV) did not exist. One of its diploid relatives *N. glutinosa* was known to be resistant to TMV. As it has a different genome constitution, its chromosome failed to pair with tobacco chromosomes. Clausen and Goodspeed (1925) doubled the chromosomes and obtained fertile plants from the hybrid between the two species. Repeated back-crossing with tobacco has resulted in the reconstitution of a complete set of tobacco chromosomes plus one extra *glutinosa* chromosome carrying resistance to TMV. Similarly, by chromosome substitution the resistance to black shank was transferred from *N. plumbaginifolia* to *N. tabacum.*

Coffey (1956) was able to transfer a resistant gene from *A. speltoides* to common wheat through the help of an amphiploid of *T. dicoccoides* × *A. speltoides*. Sears (1956) used a slightly different procedure for the transfer of leaf rust resistance from *A. umbellulata* to common wheat. As the two species did not cross with each other, a third species *T. dicoccoides* was used as bridge between the two. By repeated backcrossing of the amphidiploid *T. dicoccoides* × *A. umbellulata* to wheat, a trisomic plant was isolated with 21 pairs of wheat and an extra chromosome of *Aegilops* carrying the resistant gene. This plant was irridated prior to meiosis and its pollen was applied to a normal plant. Among several translocations obtained in wheat chromosomes, one of them had a small segment of *Aegilops* chromosome carrying resistant gene. Using the irradiation procedure, Knott (1961) was also successful in the transfer of a chromosome segment carrying resistance from *Agropyron* to common wheat.

Other important examples are the transfer of late blight and charcoal rot resistance from *Solanum demissum* and

S. chacoense, respectively to the common potato (*S. tuberosum*).

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Crop Improvement Through Hybridization

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Man has long been acquainted with the uses of hybridization which has served him in achieving his material aims. However, due to lack of theoretical basis the significance of hybridization was obscured for a long time and it depended on chance research and discoveries. Camerarius (1694) discovered sex in plants which assured the utility of male parent in the continuance of heredity. Koelreuter (1760) was the first to carry out hybridization experiments on tobacco. Later on, similar experiments were carried out by Knight and others. Uptill 1,900 when Mendel's laws of inheritance were rediscovered, knowledge about inheritance of characters was lacking. Now it was clear that the characters were controlled by genes and the inheritance of the characters was based upon set principles. This and the subsequent developments about the knowledge of genes and their role in heredity made it possible for the breeders to combine the useful characters in individuals according to necessary objectives by following various hybridization techniques. Hybridization in plants has enabled the scientists to produce new hybrids and varieties in practically all the important crops which in many countries have revolutionised their agricultural production. These varieties have the potential of giving much higher yields than the previous ones. Hybridization holds great promise in developing crop varieties which could make new break-throughs in crop yields and thus solve, to a great extent, the food problem in the world.

Objectives : Continued selection leads to no further

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improvement in crop plants. In order that selection may continue, variation must be present. The breeder seeks to induce variation by different methods and hybridization is one of the most desirable and effective means to achieve the desired ends. After effecting hybridization, selection of types with desirable combination of characters in one individual is possible. Variable characters may lie scattered in different varieties, races or species and by repeated hybridization, a single type combining all the good characteristics is evolved.

The proportion of homozygotes in a population is reduced with the increase in the number of factors responsible for the inheritance of a particular character. Here again by hybridization, it is sought to bring into a single individual as many of the useful charactors as possible. Increasing crop yields still remains the most important objective of the breeders particularly in the under-developed countries. This in no way minimises the importance for the breeding of varieties resistant to various pests and diseases which are widely adapted to various agroclimatic conditions. Quality has to be kept in view while breeding new varieties. Due to the technological advancement, the varieties must also meet the industrial requirement.

Achievements : The story of hybrid corn production in U.S.A. is well known. There are many hybrids at present in the market which are capable of giving much higher yields than the open-pollinated varieties. New hybrids are continuously being developed and the old ones are being improved. Hybridization is frequently resorted to for the improvement of single inbred lines, if these happen to become susceptible to certain diseases or pests or otherwise deteriorate in performance. Instead of rejecting the hybrid as such, the weak inbred line is improved.

After the successes obtained in the production of hybrid corn in U.S.A., the work on hybrid maize, in other countries was started. The Mexico-Rockefeller programme was started in Mexico in 1941-42. Working as a team the Mexicans and Americans collected and tested 2,000 varieties of corn, out of which 16 proved superior. Meanwhile geneticists not satisfied with singling out the best of the natural Mexican varieties, began crossing selected local and imported strains. Within five years eight new hybrids were

produced. In the 1948 yield trials, the yield of 125 bushels per acre was obtained with a new variety Rocamex V-7 as against the previous yield of 45 bushels per acre. By 1950 there was enough seed to plant 1.5 million acres. In 1964 Mexico exported 28,2,000 metric tons of corn.

In addition to U.S.A. and Mexico considerable success in increasing the corn production has been achieved in other countries including India by the use of hybrid seed. The hybrid Ganga 101 as well-known in India.

The success of hybrid corn has stimulated considerable interest in case of other crops as well. Outstanding achievements have been made in millet, sorghum, onion, squash, tomatoes, eggplant, pepper and watermelon, etc. The development and release of *Bajra* No. 1 (H.B-1) is an outstanding example in India. This hybrid has been developed by Dr. D. S. Athwal of Punjab Agricultural University, Ludhiana. Its performance in producing 88 per cent higher grain yields than the local control variety has been outstanding. This variety also tillers profusely, is resistant to lodging and downy mildew and shows partial resistance to rust under field conditions. This is the first such millet variety to go into commercial introduction. As a result of further hybridization in millets, bristling has been incorporated into several experimental pearl millet lines and hybrids as a partial measure of protection against birds. Two sorghum hybrids CSH-1 and CSH-2 have been released in India within the last few years. These hybrids are capable of giving about 200 per cent higher yields over the local varieties.

Although sugarcane has been cultivated in India for thousands of years, little effort was made until recent times to improve the yield which was as low as eight to ten tons per acre. As a result of the research at the Sugarcane Breeding Institute Coimbatore, a number of new improved hybrid varieties have been produced which are now grown in about 95 per cent of India's sugarcane area. Some have found their way into other countries including Cuba, South Africa, Australia and the United States. About thirty varieties developed at Coimbatore (with the label co) are at present in commercial cultivation in India and other countries.

The average yield in India for 1964-65 was 19.4 tons per acre and the scope for further improvement is indicated by the achievements of the individual growers; the record figure for the northern India and southern India are 89.1 and 150.5 tons, respectively. These achievements may be possible only under ideal conditions but the experts believe that average target yields of 30-35 and 40-45 tons per acre for the two regions are by no means unrealistic.

Under the Mexico-Rockefeller programme, after maize, the next crop to be tackled was wheat. Hundreds of strains were collected from various parts of the world. There were selection tests and inter breeding as a result of which 12 varieties were developed and found rust resistant as well as adaptable to the Mexican climate. In 1948, farmers for the first time, could grow high-yielding, high quality wheat during the rainy season. The yield potential of the new varieties was about 50 bushels as against 25 of the old tons. Since then more new varieties of wheat have been successfully developed. By 1962, it was estimated that 95 per cent of the wheat grown was of the improved varieties. Mexico stopped importing wheat in 1956. Yields of 70 bushels per acre are now frequent. New dwarf varieties can produce up to 115 bushels.

The successes in maize and wheat production paved the way for new research aimed at improvement in potatoes, beans, sorghum, barley, forage and pasture legumes and grasses. New varieties of potatoes have been developed through hybridization which have assured the production of this crop in Mexico and potato production has almost been doubled.

Mexico has become a nation in which as one authority comments "food production has outrun human reproduction". Another observer adds "never in history has a nation increased its food supply so fast".

The story of Mexico could be repeated in India as well as in other under-developed countries. Only a well-planned hybridization programme has to be followed. The introduction of Mexican wheat varieties in India is well-known. These varieties are capable of giving about 70 quintals of grain per hectare. New varieties such as PV-18 and Kalyan-227

developed at Ludhiana out of the breeding material obtained from Mexico have the potential of giving over 100 quintals. This is just the beginning of the story. Still, the quality of these wheats has to be improved to suit the Indian conditions by crossing possibly with the local wheat varieties. It might be possible to develop the varieties which would read the mark of 150 to 2,200 maunds per acre and all this through hybridization. Similarly in other crops, hybridization has been used frequently to develop new varieties which have boosted the production, Kufri Sandhuri variety of potato recently released by the Central Potato Research Institute, Simla, gives about 50 per cent higher yield than the previous varieties. A large number of tomato varieties developed through hybridization are on the list. The mention of a few could be made here : Marglobe, Trophy, Pan-American, etc. Rice production in the world is likely to be pushed up with the introduction of new rice varieties, particularly those developed at the International Rice Research Institute, Los Bonos, Philippine.

Hybridization has also been used as an efficient tool to seek knowledge of interspecific and inter-racial relationship of different crop plants. Such studies have been helpful to know the gene homology, centre of origin and inter-racial relationship in *Triticum* species. After seeking this knowledge, the scientists have been trying to transfer useful characters like disease resistance in wheat, high vitamin content in the tomato, by effecting hybridization. In many cases intergenetic crosses were unsuccessful due to the sterility of hybrids. In such cases many techniques like use of certain hormones, colchicine, embryoculture have been evolved to overcome the difficulties.

Limitations : There are many limitations to hybridization as a means for improving crop plants. In the case of crop plants which show wide variability in the local population, it may not be necessary to attempt improvement by hybridization. Straight selection in the local bulks may yield the desired results. Another difficulty in hybridization is the choice of parents. It is difficult to have a complete picture of genotypes particularly with respect to their interaction which requires elaborate work for analysis. Therefore, at present the choice of parents and selection in hybrids is

as much an art as science. Crossability, incompatibility and cross-sterility are other limitations of hybridization. The restriction in the number of possible re-combinations that appear in F_2 limits the possibilities of success by hybridization.

Finally, I would like to say that hybridization has been useful in developing varieties suitable to practically all conditions and meeting the objectives of breeders. There have been breakthroughs in agricultural production because of the development of new varieties. This is what can be accomplished by bringing desirable genes into a single variety by hybridization. The example of Mexico is an eye opener for others. I am sure, enough germplasm exists in every crop in the world and this can be combined and new varieties developed so that agricultural production can be increased, particularly in the under-developed countries. Hybridization with all its limitations is a tool in the hands of breeders and in the service of mankind, with tremendous potentialities. It is up to the breeders to use this tool with imagination, efficiency, energy and zeal, so that further breakthroughs can be made in agricultural yields.

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Crop Improvement through Mutation

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The basis of Mendel's laws of inheritance lies in the existance of genes in alternate forms (alleles). The inheritance of tall plants in peas won't have been known unless dwarf plants were known. The alleles arise by mutations. The term mutation was coined by De Vries in the beginning of this century and he had stated "The knowledge of the laws of mutations will presumably lead to the induction of artificial and intentional mutations and so produce entirely new characters in plants and animals. In the future it may even be possible to create better species of cultivated plants and domestic animals by the control of mutation."

Though the possibility of artificial induction of mutation and their exploitation was thus indicated in 1901 it was only in 1927 with the work of Muller that it was known that mutation can be induced in *Drosophila* by the use of radiations. A year later, Stadler showed that in barley and maize radiations can also induce mutations. Stadler expressed some pessimism in the possible use of mutation in plant improvement. However, Swedish workers particularly Nilsson-Ehle and his student Gustafsson undertook the work on artificial creation of mutation and their exploitation in plant improvement.

Mutation agents and mutation frequencies : From the beginning of the work on mutation the workers had been interested in increasing the density of mutations and thus obtaining a high number of mutations in small progenies and to control the mutation process. Through the search for various mutagens and factors modifying their effects, great

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success has been achieved in increasing the density of mutations. But success on the control of the mutation process and obtaining particular types of mutations at will, is very limited. Great promise is expected from the work on chemical mutagens on the production of specific mutations.

Besides radiations, a large number of chemicals are now known to be mutagenic. Because of ease in recording the chlorophyll mutations in barley at the seedling stage they have been frequently used as test material for studying the potency of a mutagen. The data on the frequency of chlorophyll mutation probably are of use as it has been observed that when chlorophyll mutation frequency is high, the frequency of viable mutations is correspondingly high (Table 1).

TABLE 1

Chlorophyll mutation and viable mutation frequencies after treatment with mutagens in barley

Mutagen	*Chlorophyll mutation frequency (Mutations per 100 M_1 spikes)*	*Viable mutation frequency (Mutations per M_1 spikes)*
Radiations ..	8-10%	5-9%
Ethylenimine ..	25-30%	18%
Ethyl methanesulphonate ..	50-60%	30%

Thus ethyl methanesulphonate (EMS) induces a high frequency of chlorophyll mutations and the viable mutation frequency induced by the mutagen is also high. This has been shown by Heslot and his coworkers in France and the numerous mutations induced by a series of mutagens reported in the literature, is given in Table 2.

It has been shown that the relative frequency of different types of mutations induced by various mutagens is different (Table 3).

Thus the frequency of albino mutations is high after radiation treatments whereas chemical treatments cause more of viridis and other 'rare' types of mutations.

TABLE 2

Maximum per cent chlorophyll mutations in barley for various mutagens

Mutagen	*Mutations per* 100 M_1 *spikes*
Gamma rays	17
Diethyl	43
Methyl methanesulphonate	33
Ethyl methanesulphonate	57
n-Propyl methanesulphonate	26
Iso-propyl methanesulphonate	20
N-Butyl methanesulphonate	28
Ehtyl ethanesulphonate	25
2-Chlorotriethylamine	15
Ethylenimine	28
Glycidol	22
Ethylene oxide	13

TABLE 3

Chlorophyll mutations spectrum in barley

Type of mutation	*Frequency after mutagenic treatments*			
	EMS	*MMS*	*EI*	*Radiation*
alibno ..	36%	35%	44%	50%
alboviridis and viridis ..	49%	41%	42%	40%
Others ..	15%	14%	14%	10%

EMS =Ethyl methanesulphonate
MMS =Methyl methanesulphonate
EI =Ethylenimine

In barley, there are several loci responsible for chlorophyll mutations. Even for a particular type of mutation, albino for example, there are many loci known which are responsible for it. Thus, chlorophyll mutation frequency and spectrum gives only a combined picture of mutations at several loci.

For studying the mutation process and knowing the specificity of a mutagen, it is more important to know the mutation frequency caused by a mutagen at a specific locus. Thus it might be useful to concentrate future work on working the effects of mutagens on different loci and knowing the specificity of various mutagens.

Mutation breeding :

(a) *Methodology :* Radiations (e.g. neutron, V-rays and X-rays) and chemical mutagens (e.g. EMS and EI) can be used for induction of mutations. The treatments can be done on seeds (dormant, presoaked and germinating), pollen grains, flowers, zygotes and buds. In seed propagated plants, because of convenience in treatment and handling the material, the seed is generally used for treatments. Various workers have suggested the doses which should be used for inducing mutations. In Sweden and U.S.A., radiation breeders use the so-called "critical dose", at which about 40 per cent of the plants survive. The "Critical" dose for wheat, barley, rye and oats is 10,000—20,000 r. For crucifers e.g. some oilseed crops, the "critical dose" is high (approx. 90,000 r). Gaul of West Germany recommends the use of higher doses e.g. a dose which gives 5 per cent survival. After such a dose, the mutation frequency is 2-3 times higher than what is obtained after the dose which results in 50 per cent survival. As with high doses, the proportion of chromosome aberration to gene mutations is high and also some of the mutations which may be shown at higher survival may be eliminated. Gustafsson has warned that such high doses as recommended by Gaul should not be used by the breeder.

Selection for the dominant characters can be done in the M_1 generation. As mutations are mostly recessive, an M_2 generation has to be grown. The M_1 plants are chimeric in nature and the mutation may be limited to one or two spikes only. Any new mutation will be heterozygous in the M_1 spike. In the M_2 generation, segregation for the recessive mutation will occur. 20 seeds from first 4-5 M_1 spike are space planted in short rows. In the M_2 generation, the number of families should be as large as can be possibly handled. At Syalof, about 2,000 M_2 rows are grown each year in the barley improvement programme. Only distinct

mutations are detected in the M_2 and small mutation can be recognised only when a group of plants is grown in the M_3 generation. If an M_2 plant is suspected of containing a new and valuable mutation, the M_2 plants are harvested separately and plant rows are grown out in the M_3 generation. Usually 1-3 per cent of M_2 rows are selected. The preliminary yield trial may be done in the M_4 generation, and in the subsequent generation the new mutant strain can be put in a larger yield trial along with the mother strain and other important varieties, using appropriate designs and adequate replications.

In plant breeding, the mutations are classified into micro- and macromutations. This is useful because they require different selection and breeding procedures. The micromutations involve changes in quantitative characters and hence are of greatest value to plant breeders. Such mutations affecting several genes can be detected only through the use of suitable biometrical procedures. Macromutations (or large mutations) are those deviations which are easy to recognise in a single plant. After mutagenic seed treatment, such macromutations as stiff strawed and non-lodging mutants can be selected in the M_2 generation. Micromutations e.g. mutation effecting the number of ear-bearing tillers, number of grains per ear, weight of grain and protein content, can be selected for the first time in the M_3 generation.

Besides micro and macromutations, Dr. Swaminathan of I.A.R.I. recognises two other groups of mutations, i.e. visible mutations and systemic mutations. Visible mutations, are changes which can be identified either by the naked eye or by the use of appropriate screening procedures as for example, the creation of artificial epiphytotics of diseases, the adoption of biochemical estimations etc. Systemic mutations are those mutations which either simulate an already existing taxon or necessitate the creation of a new systemic unit.

(b) *Achievements :* Up to now only few varieties have been released which are the result of direct propagation of the induced mutants which are noted in Table 4.

The release of the variety Florad of oats in 1961 by Wallace of U.S.A. is of significant importance. In 1957, a new race

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TABLE 4

Some commercial varieties created by direct propagation of induced mutant

Species	*Name of variety*	*Country*
Avena sativa ..	Florad	U.S.A.
Avena sativa ..	Alamo-x	U.S.A.
Brassica napus var. *Oleifera*	Regina II	Sweden
Hordeum vulgare ..	Jutta	Germany
Hordeum vulgare ..	Pallas	Sweden
Hordeum vulgare ..	Mari	Sweden
Pisum sativum ..	Strahlart	Sweden
Sinapsia alba ..	Primex	Sweden
Triticum aestivum ..	N.P. 836	India

of crown rust (*Puccinia avenae*) caused a great deal of concern to the breeders in U.S.A and Canada as no source of resistance to the new rust race was known in any of the commercial varieties. From a nursery of irradiated oat progenies grown in Florida, resistant plants to the new race of rust were selected. Subsequently one of the disease resistant mutants was released as new oat variety (Florad). The variety was released in three to four years time from the detection of the mutant plants.

The Pallas and Mari varieties of barley of Sweden are amongst the approved varieties which are gaining popularity in other European countries also. Pallas arose as an erectoides mutant. It is a new lodging resistant variety. Mari is an early 2-rowed variety which is attributed to mutation in a single gene.

In mustard and rape, the increase in yield has been obtained by the evolution of mutant varieties in Sweden. Both of these crops are cross-pollinated and possibility of outcrosses cannot be eliminated.

Peanuts (*Arachis hypogea*) have a very limited genetic variability. Gregory of U.S.A. irradiated peanuts with doses of 4-5 Kr. X-rays and studied 975,000 plants in the second

generation. He isolated mutants which gave an increased yield and were more suitable for harvesting by machinery and resistant to disease causing spots on the leaves. Peanuts are self pollinating and the frequency of spontaneous mutation is very low. Increases in yield are hereditary, resistance clearly showing that radiation could be a powerful factor in producing new genetic changes.

The use of spontaneous and artificially induced somatic mutations (sports) is of importance in the vegetatively propagated plants. The vegetatively propagated plants often have a long period of sexual reproduction. Usually they are highly heterozygous. The conventional methods of cross-breeding are ten times, more time consuming and sometimes not possible. Radiation has been successfully used to induce mutations in potatoes, in fruit plants like cherries, grapes and apples and in flowers like chrysanthemum.

The reasons that not many varieties have been produced through mutation breeding are many. Firstly most of the breeders throughout the world use very little of their time, energy and funds in mutation breeding programme. Their interest in mutation breeding is generally short lived. They will lay an experiment on mutation breeding in some far away neglected field and the maximum they will do is study the effects of radiation on various characters. Publish them and forget about it. Secondly, many of the workers induce mutations in varieties which have gone out of date. For theoretical consideration, pure homozygous material is more suitable, thus the use of old varieties is common in the mutation experiments. The new mutations which are induced in these varieties may already be present in the improved variety. Thirdly, in the past too much emphasis has been laid on macromutations. The workers want to immediately produce some useful mutation and release it as a commercial variety. There are cases where the mutations were induced in commercial varieties and released in a short time e.g. the evolution of the awned variety NP 836 which was developed from awnless variety NP 799 by mutation at I.A.R.I. In fact small mutations which are recognized with certainty only from the M_4 generation, may be of more value in plant breeding and it will take another two generations to test them before knowing their worth.

In many instances, a new mutant may not be of immediate importance to a breeder, but if that character is incorporated into the commercial variety, it may be of economic value. For example, we have discovered a mutant in barley in which each tiller has many nodes (15-20). In this mutant, some of the nodes show spike bearing branches. Normally each barley tiller has one spike but in this mutant, up to five spikes have been recorded on one tiller. The spikes are of small size and are of no immediate commercial importance. However, if the character of nodal branching can be incorporated into some commercial variety and if the individual head size is not reduced, such a mutant will be of great economic importance.

Concluding remarks : There is no doubt that the success of plant breeder depends on the existence of genetic variability in the population. For searching and exploiting variability in the population, plant exploration and introduction, intergeneric, interspecific and intervarietal crosses are done. Mutation research can be considered as a useful supplement to the conventional methods of breeding.

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Molecular Mechanisms of Mutation

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One of the fundamental problems of mutation genetics is to provide answer to the questions :

(i) What are the series of events that lead to a mutation ? and (ii) How is the chemical structure of the gene altered in mutation ?

The present discussion will be confined to the second question, i.e. to indicate the different types of molecular changes involved in the mutation process.

Most of the mutations result from alterations in the gene. Since the genic material consists of deoxyribose nucleic acid (DNA), it is now an accepted fact that DNA is the principal target for the origin of mutations. This necessitates an understanding of the structure of DNA in order to study the mutation process in molecular terms.

The structure of DNA as proposed by Watson and Crick is almost an accepted one now. According to their model DNA is composed of two chains in the form of a double helix. The backbone of the chains consists of sugar-phosphate bonds which have opposed polarities ($3^1 \rightarrow 5^1$ bonds for one chain and $5^1 \rightarrow 3^1$ for the other chain). The two chains are held together by pairing between purine (Adenine and Guanine) and Pryimidine (Thymine and Cytosine) bases. The bonds are always between Adenine (A) and Thymine (T) and between Guanine (G) and Cytosine (C). Because of the specific base pairing the two chains are complementary. The planes of the bases are perpendicular to the main axis and

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successive bases are separated by a distance of 3.4 A. There is no a priori restriction on the sequence of bases in a chain. The genetic information resides in the form of a code in this unrestricted sequence of the four bases (A, G.T. & C) in the chain.

The DNA molecule reproduced itself by separation of the two chains, each separated piece acting as a template along which is formed the new complementary chain in accordance with the rule of base pairing i.e. A. pairing with T & G with C.

Taking into account that in DNA genetic information resides in the sequence of purine and pyrimidine bases along the chain, one can imagine that the most likely mechanism of mutation is the one which bring about changes in this base sequence. This change in base sequence will cause a change in the genetic message which in turn will show up as a mutation. The following four types of base alterations can be visualized :

(i) Replacement of one base by another (substitution).
(ii) Loss of one or several bases (deletion).
(iii) Gain of one or several bases (addition).
(iv) Alteration of order of base sequence (inversion).

There is ample experimental evidence to substantiate that the above type of alterations form the basis of molecular mechanisms of mutation.

Of course, in order to determine the nature of the alteration in DNA which corresponds to a mutation, the most satisfactory method would be to determine chemically the base sequence in the original DNA and compare it with that in the mutant DNA. Since this is technically impossible, one must resort to indirect methods. Amongst the most promising of these is the chemical mutation research and in what follows, this will be illustrated by examples.

Substitutions constitute one of the major mechanisms of formation of mutations. Two types of substitutions are possible.

(i) In which a purine has been replaced by another

purine or by another Pyrimidine. These changes have been termed Transitions by Freese.

(ii) In which a purine has been replaced by a pyrimidine or vice versa. Such changes have been termed transversion.

The substitutions can be brought about in three different ways :

(i) Through base pairing mistakes.
(ii) Through desamination of the bases.
(iii) Through depurination leading to formation of gaps in the DNA chain.

That base pairing mistakes can take place and cause mutations has been shown by the use of 5.=Bromouracil & 2-Amino purine, analogues of Thymine and Adenine respectively. 5.=Bromouracil (Bu) tends to pair erroneously with guanine instead of its normal partner adenine. It is now supposed that Bu can either be mistakenly incorporated (error in incorporation) in place of Cytosine or that it can be incorporated correctly in place of Thymine and subsequently pair mistakenly (error in replication) with guanine. The net result is induction of transitions in the two directions (A-T→G-C) according to the moment when pairing error takes place. 2-Aminopurine tends to pair erroneously with Cytosine instead of its normal partner Thymine and in a manner analogous to that of Bu, produces transitions in the two directions.

Nitrous acid (HONO) has been shown to induce mutations through deamination of the bases. Adenine is deaminated to hypoxanthine which pairs with cytosine (and not with T) and at the next replication produces AT→CG transition. Cytosine is transformed to uracil (u) which pairs with adenine and produces GC-AT transition. Guanine is deaminated to Xanthine which continues to pair with cytosine thus producing no change. Thymine, which has no aminogroup ($-NH_2$) is not affected by HONO. Thus HONO also produces transitions in the two direction at GC.

The origin of base substitutions through depurination has been demonstrated by the use of alkylating agents or low *p*H. The most commonly used alkylating agent is the

ethylmethane sulfonate (EMS). Alkylating agents react mainly on guanine and to a lesser extent on adenine. The alkylated purines are gradually liberated from the DNA chain thus leaving a gap. The replicating DNA strand can replace the missing base gap by any available purine or pyrimidine base (leading to transitions or transversions or return to the original state) or there may be loss of the base (deletion). Similarly, exposure of DNA to low *p*H removes purine bases indiscriminately without loss of pyrimidine and produces the same affect as ENS.

Watson and Crick while proposing the structure of DNA had suggested that the various bases could undergo tautomerization into their rare emolic forms which would then have altered base pairing properties and lead to transitions. They further postulated rare pairings between two purines or two pyrimidines which would produce transversions. This in their view could account for the origin of spontaneously arising mutations.

The origin of mutations through loss of a base or addition of a base has been shown by the use of certain acridine dyes as mutagenic agents. The molecules of these dyes insert themselves between two successive bases and increase the distance between these bases to 6.8°A (the usual distance being 3.4°A). Consequently, if a molecule of acridine is inserted between two successive bases of the DNA strand which is acting as a template for the synthesis of new DNA, a space will be left between the two bases of the template strand which can be filled by an extra base in the new strand thus leading to the addition of a base. Alternatively, if the molecule of acridine is inserted between two bases of the new chain being synthesized, thus separating the bases by 6.8°A, a base will be missing in the new DNA chain and this will lead to the loss of a base. The errors introduced in such a manner will be copied as such during the next replication and transmitted.

It must be emphasized that one must not get the impression that the mutation process has been fully understood but it is only the clarity of concept which has been achieved. Starting from a knowledge of how the molecular constituents of the genetic material are put together it has been possible to construct a working model of the mutation process at the

molecular level. An altered base sequence in DNA is not yet a mutant organism. There are many steps that lie between the application of the mutagen and emergence of a mutant clone of which we hardly know any thing as yet. Future research is oriented towards understanding these various processes with the hope to be able to control ond direct the mutation processes to ones own advantage.

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The Chromosome and the Varieties

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The evolution of better crop varieties has been going on since domestication of plants by man. Varieties of the past were end products of minor improvements made in succession by the early plant breeders. Present day crop varieties are highly improved over their ancestors and are the outstanding achievements of scientific agricultural research. Plant breeding today, unlike that in past, is based on scientific principles developed through some basic sciences mainly genetics, cytology and mathematics. The modern plant breeder is not satisfied with only minor improvements but plans for a major breakthrough and often succeeds in this endeavour. He can feel proud of the achievements which receive appreciation from his fellow scientists and common man alike. For a man on the street, this is really a type of research which is most useful and desirable of further promotion, because it produces immediately applicable results. He often fails to appreciate the significant role which is played by some fundamental discoveries in bringing to him better crop varieties. This is because his knowledge is only confined to newspapers and some popular magazines and it is not well up to his comprehension to connect basic discoveries with applied research.

Plant breeding is the scuccessful development of strains, changed genetically and exhibiting improved qualities according to human demand. It is a field of applied genetics aided by other sciences related to agriculture and a few basic sciences like biochemistry and mathematics. The information provided by Mendelian Laws and Chromosome Theory of Inheritance in the beginning of this century prove to be very significant in plant breeding. This immediately led to the production of hybrid maize and some pure line varieties of other self-pollinated crops. The breeding pro-

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cedures were further refined and based on more systematic and scientific lines as the knowledge about genes and chromosomes advanced from day-to-day. The discovery of genes for male sterility in crops like Sorghum, Onions, and *Bajra* was very useful in producing high-yielding hybrid varieties in these crops, which otherwise would have been impossible due to difficulty in controlling pollination. Dwarfing genes are being usefully employed in some crops. In wheat we have dwarf varieties which can tolerate high fertilizer application and are resistant to lodging, thus giving higher yields. In Maize and *Bajra* also, such dwarfs show a promise of high yield.

The knowledge of biochemistry has provided efficient selection procedures in breeding crop varieties, superior in some quality traits, e.g. protein and starch content. Also, the information on the chemical nature of genes and chromosomes helped in better control of some genetic mechanisms like mutation and recombination, controlling variation in plants. Some mathematical techniques have enabled plant breeders to utilize the existing variability much more efficiently, by separating the heritable and non-heritable components. In the last two or three decades, such biometrical procedures have been extremely useful in the improvement of some complex characters like yield.

The impact of some basic sciences on genetics has been so much in the last sixty years, that each one merged with it, resulting in many independent branches of genetics. It is agreeed by everyone that no other science has develoed so fast as genetics. Today we have Cytogenetics, Population Genetics, Biometrical Genetics, Molecular Genetics, Biochemical Genetics and some others, each contibuting in its own way towards better understanding of the mechanism of inheritance. Most of these branches play a vital role in the present day animal and plant breeding programmes. Here, I will confine myself only to the usefulness of Cytogenetics to a plant breeder.

Cytogenetics, which is the correlated study of genetics and chromosome behaviour, has made some very significant contributions in understanding the natural evolution of many crop plants and also in planning new breeding procedures. Some of the very fundamental discoveries on

The Chromosome and the Varieties

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The evolution of better crop varieties has been going on since domestication of plants by man. Varieties of the past were end products of minor improvements made in succession by the early plant breeders. Present day crop varieties are highly improved over their ancestors and are the outstanding achievements of scientific agricultural research. Plant breeding today, unlike that in past, is based on scientific principles developed through some basic sciences mainly genetics, cytology and mathematics. The modern plant breeder is not satisfied with only minor improvements but plans for a major breakthrough and often succeeds in this endeavour. He can feel proud of the achievements which receive appreciation from his fellow scientists and common man alike. For a man on the street, this is really a type of research which is most useful and desirable of further promotion, because it produces immediately applicable results. He often fails to appreciate the significant role which is played by some fundamental discoveries in bringing to him better crop varieties. This is because his knowledge is only confined to newspapers and some popular magazines and it is not well up to his comprehension to connect basic discoveries with applied research.

Plant breeding is the scuccessful development of strains, changed genetically and exhibiting improved qualities according to human demand. It is a field of applied genetics aided by other sciences related to agriculture and a few basic sciences like biochemistry and mathematics. The information provided by Mendelian Laws and Chromosome Theory of Inheritance in the beginning of this century prove to be very significant in plant breeding. This immediately led to the production of hybrid maize and some pure line varieties of other self-pollinated crops. The breeding pro-

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cedures were further refined and based on more systematic and scientific lines as the knowledge about genes and chromosomes advanced from day-to-day. The discovery of genes for male sterility in crops like Sorghum, Onions, and *Bajra* was very useful in producing high-yielding hybrid varieties in these crops, which otherwise would have been impossible due to difficulty in controlling pollination. Dwarfing genes are being usefully employed in some crops. In wheat we have dwarf varieties which can tolerate high fertilizer application and are resistant to lodging, thus giving higher yields. In Maize and *Bajra* also, such dwarfs show a promise of high yield.

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structure and behaviour of chromosomes have provided basis of the specialized breeding procedures. Breeding methods based on following cytogenetic techniques can be considered :

1. Changing the Chromosome Number (Polyploidy).
2. Changing properties of genes and chromosomes (Mutations).
3. Alien gene substitution.

Polyploidy : Some thirty years ago, polyploidy was being used more as a novelty than a breeding procedure. But summarizing the earlier work, Levan in 1945 suggested how autopolyploids could be utilized for breeding better crops. It was pointed out that crops which have low chromosome number and are cross-pollinated, having importance for vegetative parts, would be more suitable. Following this, polyploids were produced in many fodder crops and some seed crops, and a significant progress was made in many cases. Tetraploid clovers are now cultivated widely in Sweden. Svalof's Ulva, a tetraploid variety of red clover is superior in fodder yield and resistant to nematodes while the parent strain "Ultuna" is susceptible. In India also, 'Pusa Giant Berseem' which is a tetraploid has been released in 1965. It gives 25-30 per cent higher yield of fodder and is more resistant to cold. The main advantage of this variety is its capability of giving good fodder during peak winter months when there is an acute shortage of fodder. Successful results have also been obtained in some root crops like turnips and sugarbeets. Tetraploid turnips have given higher yield than diploids and tetraploids and are being used commercially. Even among seed crops there is some success. Tetraploid rye and tetraploid toria have shown a promise of increase in seed yield. In horticultural crops also autopolyploidy has been utilized effectively in producing better crops and ornamental plants. Seedless watermelons which are triploid, are extremely popular today. Tetraploid grapes are cultivated extensively in Japan, England and U.S.A. In Sweden, tetraploids of spinach and apple have been released for commercial growing. A tetraploid variety of radish is being grown in Japan. In breeding ornamental plants, polyploids have been of immense value because of their large flower size and increased period of blooming. Tetraploids of snap-dragon, zinnia and chrysanthemum are excellent flower types and are in great demand.

Another type of change in ploidy, which has not been exploited much so far is Haploidy. Haploid when treated with colchicine would produce a completely homozygous diploid individual—a state which is difficult to attain through selfing. This technique has been utilized in hybrid maize breeding. Haploidy is also desirable in breeding programmes of some of the crops which are natural autopolyploids. In potato, which is autotetraploid (2n=48), breeding procedure is complicated due to tetrasomic inheritance but if the breeding is done at haploid level (2n=24), this difficulty can be overcome. There are also indications that higher tuber yields are obtained at haploid level, as compared to diploids. Such uses of haploidy can be made, provided the ways for increasing their frequency are more clearly defined.

Allopolyploidy, where chromosome sets from different sources are combined in one genotype, have been of comparatively less direct use in crop breeding. However, its use in tracing out the ancestory of crops is very valuable. Alloployploidy also helps in overcoming sterility barriers in wide crosses, which can be of use in plant breeding. Mention can be made of allopolyploids of wheat-rye (*Triticiale*) and radish-cabbage (*Raphano-brassica*). There are indications of some utility of *Triticale*, but the latter is more of a fancy and its usefulness is very much doubtful. Nevertheless similar work involving closely related species e.g. in genus *Brassica*, may bring some practical results.

Aneuploidy, where there is irregular increase or decrease in chromosome number (2n±1, 2n±2) has been very useful in locating genes and establishing linkage relationship between various characters in many crops like wheat, tobacco, tomato, maize, etc. Aneuploids have also been employed to study the effects of duplication of gene blocks and whole chromosomes. Such studies may be important in future breeding plans.

Mutations : Mutations, the heritable changes attributable to the changes in genes and chromosomes have been well utilized in plant breeding. This was made possible by the fundamental discoveries of workers like H.J. Mullar, L. J. Stadler and C. Auerbach that certain ionising radiations like X-rays and chemicals (mutagens) can induce mutations. The techniques of inducing mutation were further refined by the discovery of chemical nature (DNA) of the genetic material

and the availability of certain specific mutagens affecting particular bases in the DNA molecule. Some very specific gene mutations could be induced by choosing the specific mutagens which may affect only a particular site in the chromosomes. Mutagens were used to break tight linkages between desirable and undesirable genes and induce duplications of certain desirable genes showing dosage effect. These findings were of great benefit for plant improvement.

Brief mention is made here of some of the achievements in plant breeding through the use of mutagens. The release of lodging resistant barley varieties 'Pallas' and 'Mari' derived from variety 'Bonus' by Professor A. Gustafsson in Sweden was the first significant success of mutation breeding. This was followed by release of 'Stralart', variety of peas and 'Primex' white mustard from Sweden using induced mutations. Another variety of oats, 'Florad' was evolved by mutations, possesing resistance to crown-rust disease, in U.S.A. In India, awned wheat variety NP 836 was produced from an awnless variety NP 799. These are a few of the qualitative changes induced by mutagens that led to the production of successful varieties. Another still vital role of induced mutations was discovered in 1956 when it was shown that new genetic variability could be created for various quantitative characters. Further improvement by selection in an otherwise static population, was, therefore, possible as shown by W.C. Gregory working on groundnut, in U.S.A. Today it is known that almost all the characters in crop plants can show this type of improvement where no success can be achieved by simple selection and this is entirely a new field of the use of radiations and chemical mutagens in plant breeding.

Induced mutations have been also successful in creating variation among some vegetatively propagated plants. This has been very useful in some fruit crops where sexual recombination is not possible. Changes in fruit colour have been reported in apples and peaches through induced mutations. Self-thinning mutants in grapes obtained by Professor H. P. Olmo of U.S.A. are known for their looseness of the bunch with increased berry size. This mutant involves a small interchange between chromosomes which results in sterility of some buds, thus reducing compactness. Somatic mutations can produce very desirable results on the varie-

gation of leaves and petals in some ornamental plants. Such mutations have been obtained in ornamentals like chrysanthemum, carnation, roses and tulips, which have been used in producing new varieties.

It might be worth pointing out here that successful work with induced mutations required considerable effort and should not expected to be just irradiating a few seeds or plants and hoping for the rest to be done by the magin of nuclear energy.

Alien gene substitution : Yet another highly interesting, though complicated, use of the chromosome manipulation technique is to transfer certain desirable genes from different varieties and even genera, into a commercial variety. This substitution may be confined to one gene or a set of genes from 'donor' to the 'recipient' variety, through a combination of different cytogenetical techniques such as aneuploidy, and induced translocations accompanied by efficient selection of plants in the field.

It was E. R. Sears in 1956 working on wheat in U.S.A., who showed how a small segment of the chromosome from *Aegilops umbellulata* carrying a gene for leaf rust resistance, can be transferred to *Triticum aestivum*. Similarly, genes of *Agropyron* giving stem rust resistance and gene of *Secale cereale* giving leaf rust resistance have also been transferred to wheat chromosome. Ralph Riley of England has very correctly termed such procedures as synthesis of improbable genotypes by chromosome "engineering" to meet the requirements of a plant breeder. This approach in cytogenetics is so far unmatched in the history of plant improvement.

Conclusions : From the above discussion it can be inferred how the very fundamental knowledge about chromosomes and their manipulation can be helpful in plant improvement, which is applied research. Still more detailed information on the effects of numerical and structural changes in chromosomes, their chemical nature and the action of different types of radiations and chemical mutagens on them, would be highly desirable and useful in providing better and refined techniques in plant breeding. Such 'pure' research, therefore, becomes absolutely necessary and should be developed along with applied research.

In underdeveloped countries, such as ours, where the funds available for research are limited, it is often desirable to confine the work of research laboratories only to those leading to direct benefit. But it cannot be denied that the progress and development in any field, is dependent upon scientific investigation and after sometime this progress becomes a function of the scientific effort or a nation. We, therefore, cannot neglect basic research in any field at any time. It is often pointed out by experts on planning Science Policy that no applied research laboratory can develop into an effective centre of research unless it allows the fundamental research to take roots and prosper. The two aspects of research are constantly throwing problems to one another—a process that serves to invigorate both. Moreover, it is the basic research which fires the imagination of young scientists.

It is also essential to mesh the science policy with our national goals. National goals are not always the same; the science policy has, therefore, to be broad based. Almost all types of scientific research can contribute towards some national goals. For example in U.S.A. and U.S.S.R. at present the national goal is for putting the man on moon. Thus all the research in various fields becomes immediately oriented towards this national goal. The immediate assessment of some highly fundamental discoveries is not possible, but these have always led to significant advancement in technology and development in various fields even other than their own. It depends mainly upon how further research is channelised. I will conclude with a story of the lady who asked Professor Benjamin Franklin after he had demonstrated a new finding of a purely fundamental nature, Professor Franklin, what is the use of it ? and Franklin replied, "Madam, what is the use of a new born baby ?"

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two sides of the organ, resulting in a curvature. These very substances, later termed as auxins, were also considered responsible for straight growth as well.

F. W. Went (1926) carried out very systematic and painstaking work in this field. He is credited with collecting the substance in agar blocks and providing with a highly sensitive test for auxin bioassay which is used even today. Attempts at chemical identification of the substance lead to a controversy between three substances, viz., auxin, a, auxin b and heteroauxin. Of these, auxin a and heteroauxin were isolated by Kogl and his associates from urine and auxin b from corn germ oil. Heteroauxin was identified a indole-3-acetic acid (IAA) and is recognized now as the principal auxin of the higher plants.

This was followed by hetic activity in many laboratories of the world to determine the roles played by naturally occurring auxin. The subject attracted the attention of brilliant workers like Thimann, van Overbeek, Galston, Bonner, Skoog, Gustafsson, Nitsch, Burstronm, and Bennet-Clark, to name only a few. It was soon found that auxins control growth (especially cell elongation) of stem as well as root, tropic movements, abscission, longevity and aging, organ differentiation, fruit development, growth of seeds etc. They were also found to be responsible for the phenomenon of apical dominance, whereby auxin diffusing from the tip somehow keeps the lateral buds in a dormant state and being thus responsible for coordinated growth of plant parts. An interesting fact that emerged out of these studies is that auxins are effective in extremely minute quantities and may inhibit growth, instead of promoting it, when physiological limits of auxin concentrations are exceeded; different organs have been found to vary widely in their tolerance to varying auxin levels.

Synthetic auxins : Zimmerman and his associates, from 1935 onwards, introduced certain synthetic chemicals, which were chemically quite different from IAA but possessed similar physiological effects like causing coleoptile curvatures. The most notable among the chemicals are indole-butyric acid (IBA)δ—naphthalene acetic acid and finally, in 1942, the most important from the practical standpoint 2, 4-dichlorophenoxy-acetic acid (2, 4-D). These chemicals

are much more potent and stable than IAA. For instance, 2, 4-D is 100 times more potent.

Auxins and agriculture : Fundamental discoveries in the field of auxin research soon led to their application to numerous problems of practical agriculture. A detailed account of these practical applications would be beyond the scope of this talk. I shall content myself with only a few of the major applications.

Flower inductions : Application of NAA has been practised for inducing pine-apples to flower at will. Whole fields can thus be managed by a small labour force which can be kept evently busy by making the plants flower in predetermined areas. The per acre yields are increased, because many plants which fail to set under natural conditions, do so when induced.

Rooting of cuttings : A number of auxins, like IBA, NAA; 2, 4, 5-T(2-4, 5-trichloro-phenoxy-acetic acid) have been widely used to bring about rooting of cuttings. As a result, a much larger percentage of cuttings produce roots; the root system is more compact and, therefore, less chances of deterioration.

Fruit setting : Gustafsson showed that auxins can substitute for pollination in bringing about development of fruits, which however, remain seedless—a phenomenon called parthenocarpy. Production of parthenocarpic fruits has been carried out in tomato, bell-pepper, egg-plant and fig with the help of synthetic auxins. Auxin application on greenhouse grown tomatoes where natural pollination is inadequate, results not only in an improvement in yield but also in the quality of fruits.

Control of fruit drops : In apples and apricots auxin application has been found to save 98 per cent of the young fruit that fall under natural conditions.

Apple fruits, damaged by frost, fall on account of death of embryos, which are the seats of production of natural auxin. Auxin sprays of these frost damaged fruits resulted in retention and normal growth of over 90 per cent of the fruit, which would otherwise be a dead loss.

Losses on account of preharvest drop of apples have been reduced by 60-80 per cent by application of a single spray of 2, 4, 5-T (2, 4, 5-trichloro-phenoxy-acetic acid). This single application of auxins is estimated to have paid off the entire amount of money spent on auxin research in U.S.A.

Application of minute amounts of 2, 4-D has been found to prevent fruit drop in citrus and thereby also controlling a serious disease by preventing the penetration of *Alternaria* pathogen.

Auxin application in the above instances has also resulted in other benefits like increased yields and better fruit colour.

Flower and fruit thinning : In contrast to the use of auxins in retention of fruit, auxins have also been used for thinning of excessive fruits in fruit trees with alternate bearing habit. The yields become practically uniform over the years.

Dormancy and storage : Auxins like NAA have been used to prevent the sprouting of potato in storage.

Weed control : Because of their selectivity, auxins have been most effectively used for the eradication of weeds. Their weedicidal action was discovered during the second world war, but on account of apparent defence potentialities of the discovery the results were not published till the end of the war. The most extensively used of a wide variety of herbicides are 2, 4-D, its sodium salt or its methyl ester, for the eradication of broad-leaved annuals and Dalapon for grasses. The use of herbicides has become a standard agricultural practice in many countries and their production in the United States today stands nearly equal to that of insecticides and fungicides.

Defoliation : Auxins at appropriate concentrations can bring about defoliation. This property has been used in modern warfare to bring leaf fall in thick jungles for exposing hidden enemy to view.

Gibberellins : The discovery of gibberellins has been a very interesting result of investigations into the "bakanae" disease in Japan. Bakanae, meaning foolish seedling, is

characterised by highly abnormal stem elongation, yellowing of leaves and sterile earheads. The toxic principle was found to be gibberellic acid, a metabolic product of the fungal pathogen *Gibberella fujikuroi*. About half a century later, when in 1950 it attracted the attention of occidental workers, vigorous investigations started on the chemistry of the toxic principle and its effect on plants. A number of other similar substances were isolated and chemically characterised and the generic term gibberellins was given to these substances. Today 13 definite chemically characterised gibberellins are known and representing as $GA_{1,2,3}$....GA_{13} in addition to a large number of gibberellin—like substances having gibberellin activity but not yet chemically characterised. $GA_{1,2,3,4,5,6,7}$, have been found to be endogenous to higher plants and thus qualify to be called hormones. Gibberellins were found to affect plant growth and development in a remarkable manner. Much fundamental work went into an elucidation of the physiological roles of these substances. They bring about linear growth in organs or under conditions where auxins have no effect. For instance, they are ineffective in the elongation of cereal coleoptile but control the growth of the enclosed embryonic leaf where auxins are ineffective. Similarly, they bring about elongation in certain dwarf mutants of maize and pea, where auxins are without effect. Gibberellins have been shown to mediate many phases of growth like cell division, control of abscission, ageing, senescence etc. They can bring about induction of flowering in most long day plants, though without any effect in the case of short day species. In many species they can bring about the growth of ovaries into fruits, resembling the action of auxins in this regard. In many other respects their action is antagonistic to that of auxins.

Gibberellins and agriculture : Though too many hopes were pinned on the practical application of gibberellins, only a few of these dreams have actually been realized. Gibberellins have been used for promoting seed germination, breaking dormancy, rooting of cuttings, increasing the yield of fodder crops, improving the length of fibres in flax, improvement of fruit size and quality in grapes, production of parthenocarpic fruits etc. Their contribution to practical agriculture in comparison with that of auxins has been rather very small. An additional factor in this direction is the very high cost and lack of availability of this chemical, which is

still derived from natural sources, in contrast to the cheap synthetic auxins which are available in plenty.

Cytokinins : The discovery of cytokinnis has been an off-shoot of the tissue culture work of Skoog. The addition of coconut milk was found necessary for continued growth and differentiation of the cultures. The so-called coconut milk factor was later found to be a cytokinin. A naturally occurring cytokinin, named zeatin, has been recently isolated from corn by Letham *et al.* (1964). Its occurrence elsewhere in the plants has not so far been demonstrated, but inferred from kinetin—like activity in plant extracts. Synthetic kinins, like kinetin, have been in use in tissue culture investigations. In addition to its role in cell division and differentiation, other roles like inhibition of apical dominance, control of ageing and senescence, through a mechanism of directed transport of metabolities, have been attributed to cytokinins. Except for laboratory technique of tissue culture investigations, cytokinins have not found much practical application so far.

Retardants and inhibitors : Very recently the existence of a naturally occurring retardant has come to light. Addicott and his associates (Ohkuma *et al.*, 1963) isolated an inhibitor, named Abscission II, from young cotton fruits. Wareing (1964) isolated an inhibitor, which he named Dormin, from leaves of woody plants. Cornforth and its associates (1965) determined the chemical structure and found that abscission II and dormin were identical substances. They were also successful in synthesizing the chemical. Dormin could cause a vegetative bud to change into a winter bud by developing leaf primordia into bud scales. Wareing, therefore, considered the substance responsible for winter dormancy in woody plants. A number of growth retarding effects of this substance have been reported by Addicott's Group (Ohkuma *et al.*, 1963), Wareing (1964) and van Overbeek (1967). The inhibitory effect is reversible sometimes by GAxand and by Kinetin. A lot more fundamental work has yet to be carried out in so recent a field as this before one could expect practical applications, which seem to be many.

A group of synthetic retardants is, however, known since about 1949. Among them cycocel or CCC (Chilorocholine

chloride), Phosphon (2, 4-dichlorobenzyl tributyl phosphonium chloride), B-Nine (N-dimethylaminosuccinamic acid deserve special mention. These substances slow down growth processes and reduce plant height without causing malformations. They have been successfully used in reducing the height of a number of agricultural and horticultural plants for several advantages. Cycocel has been used for reduction of plant height in wheat and thus successfully preventing the serious problem of lodging.

Conclusions : Plant growth substances have had a tremendous impact on agriculture, no less in significance than the discovery and use of insecticides and fungicides. They have played their own role in transforming agriculture into industry relieving man of arduous and monotonous practices and in the conquest of nature, which has been modern man's constant endeavour.

Behind this impact lies the philosophy of science in the importance of fundamental research—painstaking yet most rewarding in terms of not only the prosperity of man, but also widening his mental horizons and conquering nature. I shall end up by quoting the words of Professor Kenneth V. Thimann in connection with a seminar on Recent developments in Plant Physiology held at the University of Delhi, 1957. "Yet the most fruitful research is rarely that which is undertaken with a specific application in view. Rather should one select problems for their intrinsic mystery and fascination and study them by whatever means are at hand. It must always be remembered that the most fundamental and far reaching applications come from the purest type of research. The possibility of application must be our inspiration rather than our guide.

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New ideas in Soil Fertility

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Soil fertility is defined as the capacity of the soil to produce crops. The function of soil with respect to the growth of plants is to supply essential mineral nutrients, water, air and to provide the environment for the elaboration of the root system. Since soil supplies of nutrients are seldom adequate for the most efficient growth of crops, research in soil fertility deals with the study of processes by which these soil reserves can be mobilised for the maximum growth of plants. It also involves the application of plant food elements which are in short supply through fertilizers and to study the factors which influence their availability to crops. The ultimate aim of the soil fertility investigator is to synchronise the soil-crop-fertilizer system and the associated environment in such a way that the rate of supply of essential elements is able to meet the daily requirements of the crops throughout their growth period.

Among the different disciplines of Soil Science, the fertility of soils has been receiving attention of mankind from earliest time. Writings dating back to 2500 BC mention the fertility of the land. The Romans, beginning with Cate about 200 BC through Columella in the first century A.D., knew enough about soil fertility to recommend crop rotation, liming acid soils, adding manures, growing legumes, green manuring and thorough tillage for soil improvement.

After the decline of Rome, there were few contributions to the development of Agriculture until the publication of Pietre de Crescenzi (1230-1307). He recommended an increase in the rate of manuring over that in use at that time.

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up to the end of eighteenth century, it was generally agreed that nitre, air, water, fire and earth in some way contributed to the increase of plants.

It is only during the period of rapid scientific development after 1800, that much progress was made in the knowledge of chemistry and physics and the information thus obtained has been applied to the study of soils and plant growth. In the last 30 years, much headway has been made towards an understanding of the problems of soil fertility.

Essential plant food elements : Sixteen elements, namely C, H, O, N, P, K, Ca, Mg, S, Fe, Cu, Mn, Zn, B, Mo and Cl are universally recognised to be indispensable for normal growth of all higher plants. Recently, a number of research papers have appeared where Co, V, Na and Si have been shown to be essential for the normal growth of some plants. The first nine elements are required in considerably larger amounts and are called macronutrients. The remaining elements, though epually indispensable for the normal growth of plants, are needed in extremely small amounts and are designated as micronutrients. It has been observed that a new element is added to the list of essential elements on an average of about 10 to 20 years as new techniques are devised for producing more nearly chemically pure sources of nutrients for plant nutrition studies. The identification of several elements that are needed in almost infinit-esimal amounts was long over looked because the elements were contained as traces of impurities in the chemicals that were used to supply other nutrients known to be essential or they were absorbed in adequate quantities from containers.

Soil fertility management practices in the case of the above nutrients should be regulated in such a way that maximum returns are obtained per unit of applied nutrients and losses due to leaching, volatilization and fixation in the soil after application are reduced to a minimum.

For the most efficient use of fertilizers, it is very important to know exactly the fate of applied nutrients. This involves accurate information on their recovery by crops, leaching and gaseous losses and immobilization of applied nutrients. It is only during the last 10 years that the general adoption of tracer techniques and the best biochemical procedures have

increased our knowledge about reaction mechanisms involving applied nutrients. Some of the new ideas with respect to different fertilizer elements are discussed below :

Nitrogen :

Slow release nitrogens : Studies with N^{15} tagged fertilizers have revealed that nitrogen recoveries in the crop under average field conditions often are no greater than 50 to 60 per cent of that applied. Nitrogen deficits up to 30 per cent are very common and represent real losses and have been long receiving the attention of the soil fertility investigator and fertilizer industry. The development of nitrogen fertilizer that would gradually release its nitrogen throughout the growing season or preferably over a longer period,would result in increased efficiency of its uptake by plants, minimize gaseous and leaching losses and reduce application costs. Unfortunately, while certain nitrogen compounds meet the slow release criteria, their molecules are complex and high production costs limit their use in lawns, gardens and ornamentals. So far, three nitrogen materials, urea formaldehyde, crotonylidene diurea and magnesium ammonium phosphate have been produced commerially. Urea formaldehyde is a mixture of methylene urea polymers (NH_2+CD, NH, CH_2 and OH) and usually contains 38 per cent N, of which 28 per cent is in a slowly available form, corotonylidenediurea (2_2Ox-4. methyl-6-urido-hexa hydropyrimidine). It contains 28 per cent N, of which one tenth is nitrate. Magnesium ammonium phosphate (Mg NH) PO_2H_2O) contains 8 per cent N, 40 per cent P_2O_5. Mg. Large sized particles minus 3 plus 6 mesh are expected to last over a year in the soil.

administrators in India have now recognised the importance of fertilizers in increasing food production in this country. With increasing use of fertilizers, the emphasis is going to be on high analysis fertilizers with low initial cost. Anhydrous ammonia containing 82 per cent N is lower in initial cost than any other nitrogen fertilizer. In spite of high shipping and storage costs, requirement of special application equipment and handling hazard, its use in America has sky rocketed.

Phosphorus : The availability of P^{32} tagged phosphate fertilizers has made it possible to estimate the relative amounts of this nutrient in plants derived from soil and applied fertilizer separately, a distinction which otherwise cannot be made. Availability of this tool has provided accurate information on recovery of added phosphorus, its fixation mechanism in soil, and evaluation of a soil test for available phosphorus. Studies on availability of tagged fertilizer phosphorus have revealed that only about 15 per cent of added fertilizer is available to the first crop and only 7 per cent to subsequent crops. Research has to be directed towards increasing the availability of fertilizer phosphorus.

Relative efficiency of different sources of phosphorus : On account of acute shortage of sulphur in the world which in turn determines the production of superphosphate which is the only phosphatic fertilizer most extensively used in India, efforts are being made to evolve fertilizers which do not require sulphuric acid in their production. Investigations in progress in acid soils of Himachal Pradesh have shown that rock phosphate is about 60 to 80 per cent as effective as superphosphate. Dicalcium phosphate, defluorinated rock phosphate, fused magnesium phosphate and multiphosphate were as effective as superphosphate in acid soils. In phosphorus deficient slightly calcareous alkaline soils dicalcium phosphate can also be used with advantage.

High analysis phosphate fertilizer : High analysis phosphate fertilizers which, at present, are not in use in India, but in near future they are going to find favour with farmers on account of their low transportation costs, storage and handling charges which make up a large fraction of the total fertilizer cost. Some of the high analysis phosphatic fertilizers already in use are triple or concentrated superphosphate (TSP or CSP) containing 44-52 per cent P_2O_5,

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Nitrification inhibitors : Dow Chemical Company has placed 2-chlore-6-(trichloromethyl) pyridine on the market which is highly toxic to the soil organisms that convert ammonium to nitrate but almost non-toxic to soil organisms or enzymes that convert urea to ammonium. In concentrations of 0.1 to 0.2 per cent by weight of N contained Pi ammonium and urea fertilizers, the product has shown incr tiveness in sandy soils under severe leaching conditions n clay loams subject to denitrification.

*Profes.

Hissar

analysis N fertilizer : Farmers as well as the

attention is the calibration of soil test for an individual crop grown in a given soil climatic region.

Leaf analysis : Leaf analysis has not been employed in India as a tool for predicting responses to added fertilizers. On account of considerable heterogeniety in the soil it is only in case of fruit plants with extensive root system that leaf analysis has proven a reliable index of response to applied nutrients. The tissue test for a given plant part and its age from different fruit trees needs to be calibrated in terms of fertilizer doses.

Foliar application of nutrients : Foliar application of micronutrients is a rule rather than an exception to make up their deficit in plants but this practice has not found much favour in the case of macronutrients. This is primarily due to their larger requirements which can only be met through repeated sprays and, therefore, involves lot of labour. In India, where there is an acute shortage of fertilizers, the results of a few scattered experiments indicate that the efficiency of fertilizer elements can be increased through foliar application of nutrients. Since insecticides, fungicides and herbicides are increasingly being used, the experiments for studying the efficiency of combined application of fertilizers and pesticides needs to be explored.

Effect of changing cropping patterns on soil fertility : The area under high-yielding varieties is fast increasing and the farmers are also being advised to shift to multiple cropping for meeting the acute food deficit in this country. It is high time that rate of depletion of different nutrients, under changing cropping patterns is investigated immediately. The information thus collected can be used for developing fertilizer schedules for different cropping patterns.

content increased with increasing rainfall and decreasing temperature. Russel (1963) has given the results of Broadbalk experiment which has been under continuous wheat since 1943. The nitrogen content in the top 9 inches of soil on the unmanured plot and the plot receiving no nitrogenous fertilizer has remained steady at about 0.10 per cent while one plot receiving nitrogen as sulphate of ammonia, the nitrogen content has remained steady at about 0.14 per cent. There have, however, been conflicting reports of benefits of green manuring to the succeeding crop in the rotation. Acharya *et al.* (1952 a and 1952 b), Biswas and Dass (1957) and Sinha (1957) have all reported significant increases in the organic matter and nitrogen content of the soil after inclusion of a green manure or legume in the rotation. On the other hand, Sen and Vishwanath (1943), Desai and Sen (1952), Singh (1962) and Sekhon *et al.* (1966) found very little advantage of a legume in the rotation. Sen (1958) and Randhawa *et al.* (1967) found some advantage when dried leaves were incorporated into the soil while Singh (1963) found that a slight increase in the organic carbon content of the soil after decomposition of the green manure crop soon levelled off. A number of workers, Tandon *et al.* (1959) and Kanwar and Singh (1959) reported significant increase in crop yields following legumes which were harvested for fodder, fibre or seed and sometimes these increases equalled those of green manuring of the whole plant. Whether the advantage of green manuring is predominant because of the improvement in the physical condition of the soil that they bring about needs to be thoroughly investigated. Lander (1935), Aggarwal *et al.* (1950), Kanwar, Bhumbla and their associates have all testified to the utility of green manuring in ameliorating saline sodic soils. Our policy of encouraging green manuring has been largely due to the supposed benefits of this practice which must be thoroughly probed.

Ever since agricultural chemists became interested in the problem of plant nutrition, the use of inorganic fertilizers has been steadily increasing. At the moment, crop production and world food supplies are dependent more and more upon the application of fertilizers. Recent years have witnessed a marked revolution in the fertilizer industry. Changes have occurred in both expanded production and consumption and the introduction of new materials.

Plant Nutrition—Some Random Thoughts

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Interest in the problems of plant nutrition is as old as civilization itself and yet has never lost its freshness and enchantment. Russel (1963), in his widely read book 'Soil conditions and plant growth' has traced the historical perspective of the search for the principle of vegetation. The classical works of Francis Bacon, Van Helmont, Robert Goyle, John Woodward, Jethro Tull, J. G. Wallerius, Joseph Priestely, Iran-Ingen-Housz, Theordore de Saussure, Buossingault Liebig, Lawes and Gilbert are too well-known to be recounted here.

It is now a matter of common knowledge that the plant needs large quantities of carbon, oxygen, hydrogen, nitrogen, phosphorus and sulphur for building up its tissues. Iron, magnesium, manganese, zinc, copper and boron and usually molybedenum are needed in smaller amounts to build up the enzymes. Potassium, sometimes sodium, calcium, chlorine and other electrolytes are needed for other purposes. Other elements such as silcon and aluminium, though present in the tissues of all plants, have not been shown to be essential.

For historical reasons, a great deal of attention has been bestowed on the importance of soil organic matter. Attempts have been made to build up its content in the soil, but the work of Broadbent and Norman (1948) and Broadbent (1948) and Joffe (1955) indicates that green manuring cannot be expected to increase the organic matter content of a soil. Jenny (1930) has stated that in USA, the organic matter

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In so far as phosphatic fertilizers are concerned, because of the world wide shortage of sulphur, the production of superphosphate will be progressively restricted. Ground phosphate rock, despite its low phosphorus availability, may assume some importance for direct application. Nitrophosphates are likely to be produced in larger quantity. Information on their relative efficiency vis-a-vis superphosphate needs to be built up.

The acute shortage of fertilizer in the market dictates its most judicious application. From purely economic considerations, fertilizer should be applied where it pays more. It is, therefore, essential to know the nutrient supplying capacity of the soil. In some of our soil testing laboratories, organic carbon is taken as the index of nitrogen availability in the soill Kalbande (1964) studied the relationship between N uptake by wheat and its soil test for nitrogen by various methods and found that Iowa incubation method yielded a better predictability of nitrogen uptake by crops. Randhawa *et al.* (1967) also found that total nitrogen content of the organic matter in the soil was a poor index of its nitrogen availability to plants. The organic carbon content of the soil was found a poor index of nitrogen availability in Hissar soil (Sekhon *et al.*, 1967). Chaudhry *et al.* (1967) too did not observe a generally significant relationship between nitrogen response to paddy and organic matter content in Punjab soils.

Dean (1958) in his report to the ICAR expressed serious reservations about the validity of methods of estimating available nitrogen, currently in use in India. He said interalia that "except for restricted areas of high rainfall and elevation, the organic matter content of our soils is quite low and the expected release of nitrogen from the humus is probably of the order of 10 pounds per acre per year or less. An index of this rate of release is what most laboratory methods for available nitrogen are designed to measure. Is not the main variable in the nitrogen supply to Indian crops, the soil management practices of the cultivators ? These include the growing of legumes, use of manure, compost, village soil and green manures. If this is the case, except for broad general differences between zones, the available soil nitrogen as now being determined in the laboratory may have little meaning in relation to fertilizer practices. The subject as

Economic considerations are bringing concentrated fertilizers into the market. Anhydrous ammonia, 82 per cent N, is one such fertilizer. It is lower in initial cost than any other nitrogenous fertilizer, although transportation and storage costs are substantially higher and considerable precautions are required in its handling. Aqua ammonia, made by dissolving anhydrous ammonia in water, has low nitrogen content. Like anhydrous amonia, it also needs to be injected below the surface, usually at depths of 4", but it is less hazardous and needs lower cost handling equipment.

Nitrogenous fertilizers differ from phosphatic fertilizers and to some extent from potassic fertilizers as well in that they are liable to losses if not quickly utilized. Agricultural chemists and fertilizer industry have, therefore, been attempting to develop a fertilizer that would gradually release its nitrogen throughout the growing season, or preferably, over a longer period. Such a fertilizer should minimize gaseous and leaching losses, obviate the necessity of split applications and hence result in increased efficiency of uptake by plants. Several nitrogenous materials, namely urea-formaldehyde, crotonylidenedi urea, magnesium ammonium phosphate oxamide, isobutyridene, glycolurie are on the market. These slowly decompose in the soil and the nitrogen requirements over a growing season can be met by a single application but high production costs limit their application to horticultural crops (Nelson, 1965). Sindri fertilizer factory has also produced enriched coal, a slow release nitrogenous fertilizer. Chakravarti *et al.* (1966) compared its efficiency vis-a-vis ammonium sulphate. Research is also underway to enclose the fertilizer particle in a suitable coating to confer slow-release properties (Army, 1963). Goring (1961) has developed a nitrogen inhibitor N-serve, which is highly toxic to the soil organisms that convert ammonium to nitrate but almost non-toxic to organisms or enzymes that convert urea to ammonium.

Raheja *et al.* (1961) have summarised the results of a large number of experiments on nitrogenous fertilizers conducted in this country and conclude that there is very little difference between various fertilizer materials on nutrients basis. Little information is, however, available about the new materials that may become the future fertilizers. Work to evaluate them, therefore, needs to be initiated.

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a whole needs critical review and extensive additional research. The study team on Soil Testing and fertilizer use constituted by the ICAR, in its report (1963) agreed with the comments of Dean and recommended the testing and development of Iowa incubation method to determine its suitability to Indian soils. It is, therefore, essential to evaluate various indexes of nitrogen availability in order to arrive at a more appropriate standard.

Randhawa (1967) reviewed the work done on soil tests for predicting responses to fertilizer phosphorus and concluded that Olsen's method was the most reliable in acid, neutral and alkaline calcareous soils of Punjab. There is a question, however, about the critical limits that should be fixed for different crops and agro-climatic regions. The present limits are based on rather insufficient information collected from a few localized areas, and a few indicator crops.

Comparatively less work has been done on methods of soil testing and predicting responses to potassium. The Flame Photometric method is widely used to determine available potassium but very few laboratories are using it on account of frequent breakdowns of the Flame Photometer. Some work on Turbidimetric method for potash estimation has been done. More studies along the line need to be undertaken.

The correct mode of fertilizer placement and time of application is about as important as the exact quantity to be applied. The available information indicates the essentiality of drilling superphosphate at some depth in the soil. Dewit (1953) has, however, presented a theory to predict responses from a placement pattern, if response from another placement pattern is known. Cooke (1954) pointed out exceptions to this theory and Prummel (1957) also criticised it in some aspects. Singh and Black (1964), however, found that Dewit's theory held good in their experiments. More intensive work on the subject should be done.

Most of the studies on time of fertilizer application indicated that while nitrogen could be applied in split doeses, phosphate and potassic application should be done only at sowing or transplanting. Recent work of Bhumbla, Rana (1965), however, points out the utility of later appli-

cation of phosphatic fertilizers. Critical studies on this aspect are worthwhile.

The plant breeders have evolved new fertilizer responsive varieties like dwarf wheats, hybrid *bajra* and hybrid sorghum. Preliminary observations (Sekhon *et al.*, 1967) indicate that dwarf varieties may be more responsive to phosphate application than other varieties. Whether it has anything to do with root cation exchange capacity of these varieties, ought to be investigated. The nutrient utilization at various stages of crop growth should also be studied, so that time of fertilizer application could be accordingly adjusted.

Home's (1955) has outlined a new approach to the problem of plant nutrition. According to him, the optimum composition of a nutrient medium is dependent on the existence of appropriate balance between all the constituents. He has suggested a method of systematic treatments and key yields, whereby this optimum can be discovered easily by a set of far fewer treatments than an elaborate factorial experiment would demand. Very few studies have been made to date, to test this approach, but ought to be undertaken.

Micronutrients : Seven micronutrients, namely Zn, Cu, B, Mn, Mo, Fe and Cl are considered essential for plant growth. Little attention was paid till 1957 to the micronutrient requirements of crops and the micronutrient status of the Indian soils. It was generally considered that micronutrients are present in adequate quantities for optimum plant growth. Now, with the intensive use of NPK fertilizers and heavy yielding varieties of crops, the micronutrients are becoming the limiting factor for optimum yield. Kanwar and Randhawa (1966) have recently reviewed the work done on micronutrients in India till 1965.

The field and pot experiments conducted by Grewal *et al.* (1966, 1967) indicate that deficiency of zinc is widespread in Punjab, Haryana and Himachal soils and significant increases in yield of wheat, maize and paddy have been obtained by the spray application of Zinc sulphate. The analysis of surface and profile soil samples also indicate that the soils of these States contained low to medium amounts of available zinc. The deficiency of iron has been noticed in sandy soils of Ludhiana district and the sprays with

ferrous sulphates increased the yield of wheat, maize and paddy significantly. The deficiency of copper is expected in Gurgaon, Hoshiarpur, Attari, Abohar and Ludhiana soils. The responses of copper on wheat and maize have been recorded in some pot and field experiments. Available molybdenum in acidic soils of Kangra and Kulu districts and its responses on wheat have been recorded in some experiments in soils of these districts. The experiments conducted on citrus decline indicates that chlorosis is mostly due to the deficiency of zinc and iron. The sprays with $ZnSo_4$ and $FeSo_4$ reduced the chlorosis of citrus markedly.

These results indicate that the available micronutrient status of the soils of Punjab, Haryana and Himachal soils is critical and further research is needed on the following lines :

1. Micronutrient requirements of important field crops and fruit trees.
2. The critical limits of available micronutrients in soils and micronutrient contents in important field crops and fruit trees.

According to an estimate, 15 million acres of agricultural land in our country lie barren and uncultivated because of the menance of salinity-alkalinity. The problem has been engaging the attention of scientists for several decades and voluminous data obtained on their diagnosis, characterization and reclamation, which was recently reviewed by Mehrotra (1967). While most workers have emphasized the growing of salt tolerant or deep-rooted crops or the use of amendments like gypsum or press-mud, Kanwar and Bhumbla (1960) have suggested that the problem of saline-alkali soils is not only of a poor physical condition but also of fertility. In their studies, the use of fertilizers in addition to amendments was found beneficial.

Bhumbla (1967) reviewed the work of soil acidity in India and indicated from the work of Kanwar and Joshi (1964) that, apart from the undesirable chemical condition, acid soils had a fertility problem as well. Liming alone did not improve the yields, phosphorus was the most limiting factor in these soils for all crops. Among micronutrients, zinc

deficiency was the most critical. Some work has been done at Model Agronomy Trials Scheme Centre, Palampur, on the relative efficiency of various phosphate fertilizers which was reported by Bhumbla *et al.* (1967 a & b).

More intensive studies need to be taken up to delineate the fertility problems in saline-alkali and acid soils and suggest remedial measures.

Lange (1938) has shown that crop yields may be increased or decreased by changing the fertility level, depending on the initial level of fertility and moisture supply. Black (1957) has discussed the two different situations that may be distinguished in practice. The available water supply is utilized fully by the crop growing at the existing fertility level in one case but not in the other. Very little methodical work has been done in this country on the interaction of soil fertility with soils moisture while we have the largest irrigation system in the world.

The subject of plant nutrition is a vast one and it is impossible for anyone to do justice to its various inneresting and intriguing aspects in such a brief review. However, it would be desirable to initiate research work along the following lines :

1. The organic matter and nutrient build-up from growing legumes in the rotation and green manuring or harvesting them for fodder or seed and the impact on the succeeding crop.
2. Evaluation of new concentrated and slow release nitrogenous fertilizers, and rock phosphate, dicalcium phosphate and nitrophosphates.
3. Soil tests for nitrogen for different agroclimatic regions.
4. Determination of critical limits of soil phosphorus for different crops and agro-climatic regions.
5. Time and method of application of various macronutrients.
6. Demarcation of areas of deficiency of secondary and trace elements with indicator crops and soil tests for predicting crop responses to their application.
7. Fertility problems of saline-alkali and acid soils.
8. Interactions of soil fertility with soil moisture.

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Physiological Research—a Mystery Disease of Cotton

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The instances of outstanding achievement in the laboratory which have found profitable use in the field are too many to dwell on at length. The property of some chemicals to retard abscission has found extensive use in arresting preharvest fruit drop in apple. The deformative effects of 2, 4-D on the plant system has made it the king of weedicides in cereal crops. Crop lodging in sugarcane has revolutionised its manurial practices. The introduction of dwarfing genes in cereals have nearly trebled their production potential. Heterosis is now widely employed in crop improvement work. Hybrid corn in USA and Hybrid *Bajra* near home are outstanding examples of its application. The discovery of high toxicity of some phosphatic esters and chlorinated hydrocarbons has enabled man to fight the enemies of field crops successfully. New antibiotics are finding increasing use in the control of plant diseases. The perfection of the technique of artificial insemination in animals has opened up new vistas in animal breeding. The introduction of Italian honeybees has vastly improved the prospects of honey production in the Punjab. Although these examples are revealing enough, to visualise clearly the interdependence of the laboratory and the field, one needs a coherent picture of their coordination in a specific research project. This is provided in physiological investigations on cotton failures in the Punjab.

American cotton (*Gossypium hirsutum*) was first introduced in West Punjab in 1853 through Dharwar where the East India Company was making frantic efforts to produce this type of cotton for the Lancashire Textile Industry. The

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Alien nature of this new introduction together with lack of adequate know-how brought up a host of problems for the cotton cultivator. Although an improved selection, 4F, was released in 1912, American cotton witnessed several years of periodic, partial failures popularly called *tirak*.

2. *Symptoms of tirak* : *Tirak* is the technically premature cracking of bolls. May-sown cotton under the prevailing soil and climatic conditions grew luxuriantly till August. Some paling and/or dropping of leaves was noticed here and there. Dropping disappeared temporarily with every irrigation. The Monsoon rains encouraged growth at certain places. At the end of the rainy season viz, during September and October, the symptoms of disease became more marked; leaves turned yellow and red followed by heavy shedding. Dropping leaves which usually remained green were also cast off. A good many flowers and young bolls met the same fate. On the semi-denuded crop, bolls cracked prematurely. The seeds inside were immature and the lint weak. Seed cotton (*kapas*) did not fluff out in locks and picking was rendered difficult. Sometimes a cotton field had to be left unpicked as the pickers were not forthcoming to undertake this weary task. As a result, yield was reduced from 10 to 40 per cent during such years.

3. *Early views on the causes of disease* : Roberts (1929) and Thomas (1932) of the British Growing Association, Khanewal surmised that the cotton whitefly was the main cause of *tirak* and low yield in failure years. This view was later rejected by Afzal Hussain and Trehan (1933) who made detailed entomological investigations on this pest. It may be mentioned that cotton failures occurred even in years of light whitefly attack.

Milne (1928) held that very high temperatures together with low humidity during early stages of growth in May-June possibly caused a sort of heatstroke culminating in crop failure. In his view, inadequate water supply during September-October, particularly when dry, further aggravated the disease. He conjectured a number of other causes of crop failure, too, but none were supported with experimental evidence.

Trought (1930) attributed these failures to the operation

of three kinds of factors—climatic, biotic and physiological. He definitely ruled out the role of soil factors in the development of *tirak* and he felt that soil was a permanent feature and could not, therefore, be responsible for periodic occurrences on a wide scale.

4. *Results of physiological investigations:* It was left to Dastur (1944) to investigate the whole problem systematically and present a cogent and coherent explanation of the causes of *tirak*. The scribe had the privilege of being associated with these investigations from beginning of 1935 to 1943. While Dastur peeped through the microscope to locate abnormalities in the plant system, his associates investigated the properties of soil, the growth behaviour of cotton plant, and biochemical differences in the tissues of normal and *tirak*-affected plants. Various hypotheses were formulated and tested for concrete evidence. Even the symptoms of *tirak* were successfully reproduced. The study of climatic factors, however, baffled us for long but a clue was finally found. Remedial measures were devised and perfected in the field. Doubts of skeptics were met by more critical studies. The results proved to be of great practical value. The salient features of this investigation are briefly described below :

(a) *Behaviour of desi and American cotton :* Primary correlational analysis of the yields of American and *desi* cotton in the eight important American cotton growing areas over the period 1921-1935 gave a value of ranging from +0.725 to +0.915. Evidently, both types of cotton shared the distress of bad crop years and enjoyed the favours of good crop years. Why the American cotton showed abnormal symptoms of *tirak* in certain years while the *desi* did not, seemed to depend possibly on their differential response to the same seasonal factor. Normally, *desi* cotton has a high propensity for shedding flowers and bolls and ultimately retains few bolls. This proved of considerable help in bad years. The few bolls finally retained were nourished to a reasonable level of maturity which could not be called *tirak*. Though a good many seeds were still found to be immature, the lint was fairly strong. On the other hand, American cotton, being *exotic*, was not equipped with so efficient mechanism of adjustment to adverse conditions.

(b) *Critical climatic factor :* Studies of the effect of average range of temperature, mean of maximum and minimum temperature and average humidity during the three phases of crop growth, viz., early growth (May-June), peak growth (July-August) and reproduction (September-October) on the final yield did not reveal any clear association.

A clue to the real causal factor was incidentally provided by the occurrence of partial *tirak* symptoms in 1939 during the course of these investigations. It was observed that the months of September and October and the first half of November were characterised by spells of hot and dry weather extending over 10 to 15 days. *Tirak*, which was noted to occur every year on soils with highly saline subsoils, spread this year even to medium salinity areas where no signs of this disease were normally noted. The disease produced very typical symptoms. It was surmised that if spells of hot and dry weather during the fruiting period were really responsible for the wide spread dissemination of *tirak* in the Punjab, similar spells must have occurred in previous failure years too.

A detailed study confirmed the occurrence of such spells of hot and dry weather in the reported years of cotton failure, but these were not always reflected in the monthly means of maximum temperature because the days of relatively low temperature preceded or succeeded these spells of high temperature. Sometimes the spells began late in one month and continued in the early part of the next month. Thus, the monthly means of maximum temperature did not truly represent the conditions weathered by the crop.

The investigation finally centred on the calculation of the correlation coefficient between yield and degrees Fahrenheit above the normal monthly mean of maximum temperature in a spell of eight or more days in September and October for the period 1921-1940 for the districts of Lyallpur, Montgomery and Multan and for three private farms, viz., Brucepur Farm, Lyallpur; Military Farm, Okara and B.C.G.A. Farm, Khanewal. The results showed one common feature of negative values of correlation coefficients in all cases. The value of $\underline{r}$ was satistically significant in four out of six determinations mentioned above. There was thus a definite indication of fall in the cotton yield as the degrees

above the normal maximum temperature in hot spells during these two months increased.

(c) *Soil factors :* Salinity in the subsoil in irrigated areas of Punjab was found to be widespread. Its concentration varied both vertically and horizontally. While the total soluble solids in normal soils seldom exceeded 0.05 per cent, in saline subsoils this fraction gradually increased to 0.5 per cent or even more with increasing depth up to six feet. The cotton crop grown on such patches of soil showed pronounced dropping of leaves in September and October. Irrigation only temporarily revived the leaves but drooping reappeared as soon as the moisture was lost from the surface soil layer. Leaves turned dark and dull, lost freshness of green colour and shed prematurely. There was no yellowing and reddening of leaves prior to shedding. The bolls remained small and showed normal *tirak* symptoms.

The *p*H value of such soils varied from 8.5 to 9.5 as compared with 8.0 to 8.4 of a normal soil. Abnormal amounts of sulphates, chlorides and bicarbonates were found to be present from the 3rd or 4th foot donwnwards. In some cases, sodium carbonate was also present in small amount. The salts were predominantly of sodium. In some cases sodium had replaced calcium in the clay complex. The influence of sodium salts on the occurrence of *tirak* was experimentally proven by the author who reproduced the typical symptoms of disease with graded applications of sodium chloride, sodium carbonate and sodium bicarbonate in various combinations. Of these, sodium chloride was most toxic.

Light soils deficient in nitrogen were also found to be associated with *tirak*. In this case, leaves turned yellow and red before dropping. There were no signs of permanent drooping.

These two soil conditions occurred together in the same field. Patches of soil with varying physical properties, salt concentration and fertility level were found irregularly distributed. It was not strange therefore, that the distinctive role of their two soil conditions in the production of *tirak* was not understood and properly defined by earlier workers.

(d) *Interaction of climatic and soil factors :* The association of factors causing *tirak* now became more clear. Disease symptoms were noted in normal years only on extreme types of soils with saline subsoil as well as on light sandy soils deficient in nitrogen. During years of high maximum temperatures during the reproductive phase even the marginal areas and fields got involved and the disease showed wider occurrence with more universal damage.

(e) *Physiological disorders :* No major difference was noted in the growth trends of plants growing on different kinds of soils. Of course, on sandy loam soils with saline subsoil some depression was noted in growth rate during August and September due to the inability of roots to absorb enough water. On the other hand, on light sandy soils, the growth rate was a little higher in early stages as compared with that on normal sandy loams on account of extensive root development. But the limiting influence of the nitrogen factor on the growth rate appeared during the flowering and fruiting period.

In percentage distribution of total dry matter, the normal sandy loam gave relatively the highest fraction of dry matter in bolls. These soils also had more dry matter in stems than in leaves. In contrast, light sandy soils had more dry matter in leaves than in stems.

The leaves of *tirak*-affected plants were found to be deficient in nitrogen, phosphoric acid and lime from the early stages of growth, while potash became deficient from mid-August. On light sandy soils deficient in nitrogen, chloroplasts in the leaf were found to be gorged with starch grains accompanied by tannin deposits.

Growth of *tirak*-affected bolls was inhibited from the 5th week onwards while it continued up to the 7th week in case of normal bolls. The number of seeds per boll varied from 30 to 50 on normal soils, while on saline sandy loams and light sandy soils, the number varied from 17 to 25. Low potash in the carpels and low nitrogen, high potash and lime in seeds of the *tirak*-affected bolls were common features. Immaturity of seeds of such bolls seemed to be associated with low potash content of leaves and carpels. Potash deficiency was an indirect effect of certain soil conditions as direct

application of this nutrient was of little avail.

Oil formation in seeds of the *tirak*-affected bolls ceased in the sixth week while it continued up to the eighth week in bolls of normal plants.

Briefly, these physiological abnormalities in the *tirak*-affected plants were due to deficiency of nitrogen in one case and to physiological drought in the other. Immaturity of seed and lint appeared as a common symptom under both conditions although the leaf-symptoms were at variance.

5. *Remedial measures :* Besides climate, three factors were clearly involved viz., the exotic nature of the crop, nitrogen deficiency and subsoil salinity. The first condition has been partly corrected by continued selection in American cotton over the past five decades. The chances of direct introduction of *tirak*-resistant varieties from outside is not feasible in view of the high sensitiveness of *hirsutum* cottons to the environment. The ultimate variety shall have to be bred under our own condition. Viewing the nature of environment and existing soil conditions a type form of the future variety can be easily projected. It should be short-statured with small fruiting branches, highly sympodial with two or three strong main branches and very resistant to common diseases and pests. Already a coordinated breeding project on an All-India basis for evolving suitable varieties for cultivation in each State, has been launched.

Nitrogen deficiency can be easily made up by the application of inorganic nitrogenous fertilizers. The subsoil salinity can be removed by soil reclamation following standard practices. Yet in view of the mixed occurrence of light sandy soils deficient in nitrogen and light loam soils with saline subsoil any large scale leaching does not appear to be a sound proposition. The real remedy, therefore, lies in the evolution of proper management practices for the soil and crop in order to maintain the plant physiologically fit to fight the adverse conditions successfully.

This remedy was found in the late sowing of cotton. The resulting plant was small with a shallow root-system which did not penetrate deep enough to be seriously upset by the subsoil salinity. The symptoms of water stress were, there-

fore, less pronounced. The nitrogen needs of a small plant were naturally small and the crop remained fairly green for a long time. At flowering and fruiting, the late sown plant was physiologically active and more plastic in adjusting itself to the incidence of high temperatures which seriously blighted the prospects of the early-sown overgrown crop. The bolls produced were larger though fewer per plant. The seeds were also heavier. The ginning percentage was slightly low on this account.

Another redeeming feature was that the late sown crop did not mature late. If any, there was a minor delay in the date of first picking and the crop finished off along with the early sown cotton. The late sown crop had no additional demand of late irrigation nor was it liable to any greater danger of winter frost.

Smaller plant of the late sown crop, however, resulted in lesser produce per plant. This flaw was corrected by heavier seeding and closer spacing than normal. The late sown crop was also more susceptible to the attack of cotton jassid which could be kept in check with periodic sprays of insecticides.

Even without insecticide sprays, the adoption of late sowing along with higher seed rate and closer spacing has resulted in an average increase of two quintals of seed cotton per hectare at the B.C.G.A. Farm, Khanewal over a period of 15 years as compared with that of the immediately preceding period. This simple and practical remedy has stood the test of time and has eliminated a serious threat to cotton cultivation in the Punjab.

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Principles of Pest Control

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An insect or an animal may assume the status of a pest when it causes damage to farm crops or domestic animals to an extent that it is a significant economic loss. The degree of damage caused may vary a great deal and generally an arbitrary limit is fixed to give a particular insect or an animal the status of a pest. There are various ways of assessing this status and arbitrary limits fixed may change according to :

(i) Increase in the actual numbers of a pest;
(ii) The type of damage caused by an insect to a particular crop;
(iii) The change in climatic conditions and the consequent increase or decrease in damage;
(iv) The change in cultivation and harvesting methods;
(v) The change in marketing value of crop.

It is believed that between 15,000 and 12,000 B.C. Neolithic man took to cultivation of land. He selected stronger looking plants and practised closer planting of seeds in order to submit them to similar cultural treatments. Prior to this stage, the fertile areas of the world were covered by vegetation and a dynamically balanced association existed. Since the dawn of civilization, the process of selection of better plants capable of giving higher yields has continued. By this process much of the natural fauna was destroyed and the existing complex inter-relationships between various species

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of animals and plants were upset. With improved agriculture and specialized farming, man interfered with nature more and more which consequently resulted in further aggravation of the situation. In this process, many species of insects and animals perished but those which survived could obviously withstand the changed environment.

Balance was upset by other ways also. New areas and virgin lands were brought under cultivation and the crops grown provided food for species which otherwise were not important or provided conditions for the alien species from distant habitats to invade. With scientific progress man was able to remove geographical barriers such as rivers, oceans, deserts and high mountains. The removal of such barriers coupled with improved modes of transport also helped such alien invasions. In certain areas the newly-introduced crops also brought along potential pests, which flourished under new conditions.

Numerous species which lived in a state of balance under their original habitats were faced with changed cropping patterns. Whereas in the original state of balance the phytophagus species fluctuated in their numbers from year to year, the fluctuations were not so violent as to destroy the entire growth of host plants. However, under changed agriculture new patterns of animal communities were evolved which were far less balanced. In many cases cultivation of land and sowing of new crops provided suitable habitat for potential pests.

From the above discourse it appears that man is mostly responsible for the pest problems through his interference in the natural balance. Had enough attention been paid earlier to this disadvantageous interference, pest situations could have been avoided by evolving suitable preventive measures.

In countries like U.S.A., Canada, Australia and New Zealand, where agricultural development is of very recent origin and only few crops are native to the area, most of the pests are introduced ones and they have reached epidemic proportions at one time or the other. In Africa and USSR where cultivation has been started on recently cleared areas, such situations are more prominent.

In the old countries of Europe and Asia, where cultivation had been going on for centuries, this early stage of introduction, new cropping pattern, and the proliferation of alien pests had obviously passed long time ago. A sort of secondary balance is exhibited by the artificial populations sustained by agriculture. During the course of centuries the pests became old and some of them achieved a devasting status. In these countries also, some new pest introductions were experienced in modern times primarily due to improved transport facilities. The well-known examples are the San Jose scale and prickly pear in India, Australia and many other countries. Apart from such introductions some of the indigenous species of insect or other animals must also have changed their pest status with ecological changes in the environment. For instance, the mere introduction of a variety could convert a harmless insect into a pest.

Some of the environmental factors that could cause significant changes in pest status are as follows :

(a) *Susceptibility of a variety* : A new variety introduced may provide food for a longer period of time and at the same time be more nutritious as compared to the related wild plants. For example, cabbage and cauliflower provide more succulent and attractive food for a longer period of time for catterpillars as compared to the wild cruciferous plants.

(b) *Enhanced suitability of habitats* : Changes in cropping pattern and intensive agriculture may provide continuous food supply to a given pest.

(c) *Changed habitat due to monoculture* : Pests adapted to a given crop could biologically fit into that particular system, whereas, under similar conditions, other competing species may perish due to the non-availability of food throughout the year.

(d) *Changes of host-parasite relationships with changing agriculture* : This affects pest status in many ways by providing alternative hosts for parasites and by providing shelter during unfavourable seasons.

Thus we may say that an organism may attain pest status in any of the following four ways :

(i) The entry of a species into previously uncolonized habitats.

(ii) The changes in characteristics of a species, leading it to directly interact or compete with man's interests.

(iii) The increased sensitivity of man to an already existing species on account of a change in habits and activities of man.

(iv) A species may prove injurious to man due to the abundance of the host, providing a lasting increase in the supply of a limited resource, or a lasting decrease in the frequency or severity of respressive interactions, or both of these changes.

This would imply that the general evolutionary process of nature provides situations for an organism to assume pest status. Its significance to man could be attributed to circumstancial conditions which include ecological processes as well. Under the prevailing circumstances it may not be possible for man to direct the evolutionary processes but he can certainly modify the ecological events to his advantage. So it may not be possible to avoid pest situations completely but their effect on our economy could be lessened to some extent.

We can consider India as one of the oldest countries from agricultural point of view and the climate of North India is unique in many respects and insect pests of the three main climatic regions, i.e. temperate, tropical and sub-tropical, have managed to survive. Intensive agriculture involving the cultivation of both winter and summer crops provides ensured food supply to these pests.

As is the case in many other countries of the world, so also in India, various pests have attained different degrees of importance. Firstly, there are regular pests which are always found in abundance. This category includes jassids and aphids. Secondly, there are sporadic pests which rise above the economic threshold occasionally. These pests include grasshoppers, locusts, crickets, etc. Thirdly, there are potential pests which might become highly damaging if allowed to establish in a locality. Fourthly, there are special pests which gain importance under certain circumstances only.

Irrespective of the status of a pest and its source of introduction, the knowledge of its noxious activities is almost always based on the studies made after its establishment as a pest. Rarely, if ever, has this knowledge been collected before the introduction of a crop in a new country. Obviously, the introduction of a crop itself is based on economic reasons. The possible danger of pest introduction cannot be considered a sufficient reason for not inroducing a given crop unless it can be determined before hand that the damage will be far too heavy ultimately. Various countries adopt quarantine measures as a precaution against introduction of known pests into new countries, yet accidents have happened inspite of the best of efforts. Thus, the pest control research is primarily based on the hypothesis that a given pest has actually been established in a country. Therefore, both in the old and the new countries, efforts on pest control research have been very similar and the strategy for their control has often been evolved in one country and used in another.

The use of agricultural practices for the control of pests : in many cases, such practices have been evolved after a detailed and sophisticated research on a given crop pest. It cannot be generalized that mixed farming or specialized farming is good from the point of view of all insect-pests. In fact, the situation varies with different species involved. Mixed farming might prove helpful in the spread of a particular pest species but in others it may be harmful. Therefore, every recommendation has to be made with a specific purpose in mind with regard to the control of a given pest. The stubbles of a crop harbouring caterpillars during winter could be collected and burnt with advantage while we cannot be sure as to whether or not interculture of a field would actually kill a certain proportion of individuals. Hoeing and interculture may prove helpful to the plant through aeration of the soil and result in improved food supply which in turn may increase the plant utility, or more likely, compensate the damage caused by a given pest. It is, therefore, imperative to know exactly whether the benefit of interculture practices is direct or is indirect.

No doubt some useful and effective cultural practices have been devised for the control of pests, yet the gap is so large. It has necessitated the evolution of more effective and

spectacular methods of pest control, namely the chemical, biological and the ecological methods.

Chemicals, both inorganic and of plant origin as agents of pest control have been engaging the attention of a man since long. As early as 1746, water extract of tobacco leaves was suggested for the control of plum curculio. The presence of nicotine in tobacco leaves was discovered in 1828 by Posselt and Riemann. Juntikoff, an Armenian, gained information about the use of flower heads of pyrethrum as insect powder by certain tribes of Caucacus and his son started large scale manufacture of this powder in 1828. Later on this product was introduced in France in 1850. Similarly, the use of powdered tuber roots of *Derris* as an insecticide in Singapore was observed by the visiting Europeans towards the middle of 19th century. Lead and mercury compounds and arsenicals were also used as insecticides in Europe about that time. Certain organic solvents and oils and soaps were also used as insecticides against mites, thrips and scale insects. For instance, Haggerston successfully used whale oil soap for the control of aphids, red spider mites and thrips in 1842. Other groups of chemicals used as insecticides were dinitrophenols, organic thicyanates, fluosilicates, flourides, etc. Except pyrethrum, *Derris* and nicotine, almost all the compounds were, apart from being toxic to insect pests, also phytotoxic or had high mammalian toxicity. Due to these drawbacks, the chemicals were used with great caution and, in fact, in certain countries their use was banned.

The real breakthrough came during the Second World War with the discovery of DDT and other organic compounds which were highly toxic to insects but comparatively harmless to mammals. In the post-war period synthesis of hydrocarbons, organic phosphates, carbamates, etc. was intensified and thousands of such compounds are now being tested every year out of which only a few promising ones are selected for commercial use.

With the passage of time and further researches it has been discovered that such apparently harmless compounds like DDT had far reaching effects even on mammals through constant deposition in fat bodies. These insecticides when sprayed on crops or forest trees were washed by rain and

contaminated the ponds, lakes and rivers. This resulted in the pollution of fish fauna which taken as food by man caused acute and chronic ailments. Rachel Carson through her book "The Silent Spring" has voiced most forcefully the dangers involved in such applications. The hazards to mammals through indiscriminte use of insecticides had been a matter of great concern.

Apart from these hazards insecticidal control has some other inherent limitations as well; pests require resistance to insecticides; the non-target organisms like parasites and predators are killed and hostparasite relationships are disrupted. Inspite of these drawbacks chemical control still remains the most effective, the most impressive, the most economical and the most practicable method of pest control. Until and unless sound alternative methods of control are discovered, the application of insecticides is going to continue and is going to remain the most practical tool by which we can save precious crops and farm produce. Some phenomenal results of pest control have been achieved with biological methods. The use of one species of insect for suppressing the population of another species had been known to man since long. The predaceous ant, *Oecophylla smaragdina* F. had been regularly employed by citrus growers in China to reduce the number of foliage feeders since ancient times. In Europe as early as 1776, people used to employ the hemipteron *Picromerus bidens* L. as a predator of bed bugs. However, the international introduction of biological control agents from one country to another started in 1873 when Planchon and Riley introduced a predatory mite for the control of grape-vine phylloxera into France. Next followed the historic introduction of the beetle, *Rodolia cardinalis* from Australia into California in the year 1888 for the control of Cottony-cushion, scale a pest on citrus. Since then it has been introduced into various countries of the world including India, where it was introduced in 1928. Another notably successful example of biological control is the introduction of *Aphelinus mali*, a parasite of woolly aphis of apple in various countries of the world. This parasite was also introduced into Kulu Valley where it has successfully established since 1937. A classical example of biological control of weeds is that of the destruction of prickly pear in Australia by the introduced moth, *Cactoblastis cactorum*. Inspite

of these outstanding examples, the number of successes as compared to the trials made have been very few and have been confined to those cases where the pest was originally introduced accidently from abroad. The parasites or predators were later on introduced from native lands. A large number of pests in the old countries and also the indigenous pests in new countries thus, remained uncontrolled by biological methods. Many reasons have been attributed and efforts have been made to explain the circumstances under which parasites and predators would not prosper, either in the native habitat or when introduced from outside. The factors responsible for the ineffectiveness of the natural enemies are generally believed to be as under :

1. Climatic factors, such as extremes of temperature, humidity, rain or wind, which might be suitable for the host species, and not for the natural enemies.
2. Lack of pollen, nectar or honey-dew resulting in scarcity of food or water for the adult parasities.
3. Provision of insufficient shelter by unfavourable host plants.
4. Severe competition with other natural enemies.
5. The heavy mortality among the parasites by the application of insecticides used for the control of the host species.
6. Unfavourable effect of agricultural practices.
7. Inherent or seasonal low rate of reproduction of the parasite.
8. If density of the parasites or predators falls below a certain threshold, the mating of the two sexes may become scarce, as the adults have an inherent tendency to disperse, and even more thinly distributed.
9. Synchronized with various seasons the parasites and predators may migrate or aggregate away from the host population in a certain proportion every year, as do the Coccinellids. There might be ovarian diapause during certain parts of the year resulting in the suspension or further multiplication of the predators, and corresponding increase in the host populations.

Apart from these generalized factors applicable to both, indigenous as well as to introduced parasites, there are

characteristic host parasite relationships which determine the unsuitability of an introduced parasite against an indigenous pest. In those cases the unsuitability of a parasite and its limitations to control the host species may be due to the following reasons :

(a) There may be unsynchronized life cycles of the host and the natural enemies.
(b) A very similar or an allied host species may in fact have resistance against an introduced parasite as transmitted through the host plant.
(c) The host species might have a local biological strain unsuitable for the natural enemies.

Although the biological methods of control have not been successful in most of the cases on account of the limiting factors stated above but in some cases success has been achieved, and excellent results have been obtained, without much cost. It might be profitable to conduct basic studies on the behaviour and the ecology of the species which have not been controlled so far. The idea of competitive displacement (De Bach, 1964) of a pest species by the introduction of an ecological homologue needs serious testing followed by practical application. The ecological homologue may not be a pest species. If, however, it were a pest, it could be controlled through the introduction of its indiginous parasites or predators.

The field of microbial control of insect pests has been exploited eversince the beginning of 20th century. Various species of fungi, bacteria and viruses have been tried against insect pests of crops and forest trees. The virulence of the fungal spores is dependent on high temperature and high humidity conditions and, thus, their application for the control of pests is very limited. In general, the properties of the host and the pathogen, an efficient means of transmission of the pathogen, the economic threshold of the host, and the physical or biotic environmental factors prevalent, determine the success of microbial control. The virulence and persistence of the microbe, the time of its application and the coverage on the susceptible stage of host may also limit its success. For achieving a lasting control, the significance of each of the factors may vary with a specific

microbe or its host. For example, in controlling the soil inhabiting grubs of Japanese beetle, the persistence, propagation and the spread of *Bacillus popillae* spores are important. On the other hand, virulence, dispersibility and transmission of the nuclear polyhedrosis virus are of value in controlling the sawflies which feed exposed on the leaf surface. Similarly, the effectiveness of *Bacillus thuringiensis* against lepidopterous caterpillars is dependent upon the *p*H inside the insect gut as the lethal crystals produced by the bacteria are soluble in alkaline solutions only. Besides, the conditions favouring development and occurrence of epizootics in insect populations are not fully understood. The host species also display considerable variations in their susceptibility to pathogens. The number of effective species of pathogens is limited and the cost of their production is generally high. Nevertheless the microbial control has some potentials. The production of toxins by some microbes could be exploited; these could be isolated, purified and applied in the field. The latent or chronic infections already existing in the host populations could be activated by using stressors. Since almost all the microbes have a narrow host range and they do not leave any toxic residues, the existing host-parasite complex is not disturbed through their use.

During the past few years efforts for devising newer techniques have been intensified. Eradication of screw worm fly, *Cochliomyia hominivorax* (Coquerel) from the Curcao islands through repeated releases of radio-actively sterilized males has stimulated the Entomologists to persue new ideas. Subsequently, eradication of the oriental fly and melon fruit fly was achieved by employing this method on the islands Guam and Rota, respectively. Researches on the use of this technique for the control of pests like fruit flies, housefly, boll-worms, boll-weevils, mosquitoes, etc., are in progress. But this method cannot be applicable under all situations on account of certain limitations, such as :

1. lack of facilities for mass rearing of the insect;
2. high population level of the pest species;
3. sterilizing techniques hamper the mating ability of treated males.
4. the treated males are unable to disperse quickly and search their mates efficiently.

5. in consistent releases of sterilized males and protection against reinfestation.

With advancement in technology and detailed studies on habits and ecology of pest species, this method could provide a spectacular success. The successful eradication of screw worm fly, incited interest in achieving sterility through the use of chemicals. Intensive studies carried out during the past few years have shown that chemosterilants could be effectively employed for inducing sterility. However potential hazard to man and other organisms have come in the way of their practical applications. So the use of chemosterilants is still dependent upon the feasibility of devising a highly selective method of application to ensure higher safety levels.

The knowledge gained in the use of pheromones (attractants) and insect hormones is still inadequate for their practical application in pest control through behavioural manipulation of the pest species. Pheromones have a potential future in having desirable qualities like absence of residue problems and mammalian health hazards, development of resistance and biological effects on non-target organisms.

Repellants are known to be in use for temporary relief against noxious insects since times immemorial. The limitations posed by the chemical control measures have led the entomologists to look for newer methods of control. The use of antifeedants for the possible control of pests is engaging the attention of workers currently. The successful demonstration about the usefulness of antifeeding compound 24,055 by the American Cynamid in 1959 against chewing insects has opened new vistas for further research in this field. Since an antifeedant acts by inhibiting the taste receptors of a phytophagus insect in the mouth region, there cannot be any harm to the beneficial insects, the parasites, predators, and pollinators.

Control of pests by direct exposure to unfavourable physical conditions had also been practised in some cases. For example, gram cutworm larvae could be killed by direct exposure to sun after ploughing. The positive phototactic behaviour of the tobacco horn-worm and Kutra

moth had been made use of for their control through light traps. Recently, efforts have been directed towards the use of electromagnetic energy for pest control. It has been shown that stored grain pests could be killed by exposing the grain (moving on conveyer belts) to radio frequency waves and ionizing radiations. The high cost of radio frequency installations is still a hinderance for its practical application. Similarly, the cost of ionizing radiation is a limiting factor.

The above discussed methods of control have been tried against individual pests successfuly. Yet many new species have assumed pest status as, for example the apearance of mites the sparrows and some species of rodents. Geier (1966) has suggested that problems of pest control should be tackled in such a way that they assume an applied form of population ecology. The concept of "pest management" advocated by him aims at considering the means available for pest control according to their two-fold functional qualities: (i) characteristics and operation of means along with their attributes, e.g. safety, inherent selectiveness and intrinsic biological efficacy, (ii) the influence such means exert on the ecological systems.

This concept seeks to deal with populations and the abundance of a population is the function of the fitness of the innate qualities of individuals constituting that population to the operative characteristics of the environment (Andrewartha & Birch, 1954). The innate qualities could be modified in such a way that ability of individuals to perform normal life functions within the population and the environment is upset. This can be achieved through sterilization of males with ionizing radiations, chemosterilants and exposure to electronic flashes.

The characteristics of the environment may be changed to the disadvantage of pest populations by :

(a) increase in severity and frequency of environmental hazards leading to premature death of individuals;

(b) disturbing ability of individuals to locate vital requisites for successful completion of their life functions;

(c) suppressing supply of vital requisites to render the habitat unsuitable for pest species.

Thus, we may achieve control of pest species either by modifying the innate qualities of individuals of a pest population or by changing the characteristics of the environment to the disadvantage of the pest population.

Another approach to successful pest control could be that of 'integrated control' (Bartlett, 1956). This approach aims at employing more than one method for pest control and Stern *et al.* (1959) have defined "integrated control" as combination and integration of biological (including ecological) and chemical methods. According to Riper (1958), the pre-requisites should be there for devising an integrated control programme include :

(i) availability of a low density-dependent natural enemy of the pest species;

(ii) a selective insecticide capable of controlling the pest but harmless to biological control agent.

Subsequently, Bosch and Stern (1962) have outlined certain factors which need consideration before devising such a programme. According to them, the development of an integrated control programme for the alfalfa caterpillar, *Colias eurythene* in California was preceded by detailed studies on its behaviour, population dynamics, economic status, the nature, timing and efficacy of natural enemies.

After giving thorough consideration to the various pest control measures discussed above, it may be concluded that under the conditions prevailing in India :

(i) There can be no abandoning of the chemical control method. Spray schedules should be worked out to exercise effective check over the pest complexes of various crops. However, adequate attention should be paid to the proper selection and application of insecticides.

(ii) Integrated approach to pest control could be adopted where it is feasible.

(iii) Detailed studies on the ecology of various pests should be undertaken on an extensive scale. This could also lead to evolution of effective integrated control measures.

(iv) Efforts should be made to create such environmental conditions that help in keeping the pest in a state of balance and inhibit frequent population exploisons.

The introduction of resistant crop varieties can change the entire pattern of crop pests. Since a number of pests have gained prominence with the introduction of susceptible varieties there is no reason why the tables cannot be turned to the advantage of man, and the importance of pests be changed to insignificance by changing the cropping pattern or by the introduction of resistant varieties or by otherwise changing the environmental conditions which might be unsuitable for the multiplication of a given pest.

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Advances in Pest Control Research

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The pests have bothered man from time immemorial and there are records in the Vedic scriptures pointing to the control measures that were advocated even in those early times. However, with the increasing population pressure and the increased demands for food, fibre and timber it has become more important than ever before that the insect-pests be kept under control.

For the benefit of those who are not familiar with the terminology, I may make it clear at the outset that a pest is an organism which is injurious. However, this organism is a pest only because it occurs in populations above the 'economic threshold' which may in turn be defined as the population level of injurious species, an increase beyond which would be harmful to the interests of man. The term 'control' means the reduction in the population of a pest below the 'economic threshold' and does not mean a complete extermination from a given habitat for which the term eradication is correctly applied.

Pest control measures have raditionally been divided into the following categories for the sake of convenience.

1. *Legal control and quarantine* : This implies the use of laws for restriction on the spread of pests through transportation from one place to another of the materials harbouring the pests. This method does not really control a pest in the true sense but avoids or at least delays the introduction and establishment of pests which are found in another country or state or area. There has been no real

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progress in this method of control during the last few years.

2. *Mechanical control :* The use of machines hopper-dozers meant for collection and destruction of different insects has almost been given up in favour of insecticides, the use of which is much more rewarding, economical and the control achieved is far more spectacular.

3. *Physical control :* Entomologists have been trying to use heat, light, electricity, sound waves, X-rays and gamma-rays, etc., for the destruction of insects. Some of these are used quite effectively for this purpose. For example, light traps. electrocutting grids alone or in combination with light and/or suction systems, dry heating, steam heating as well as chilling and cold storage have been used successfully for the control of many pests. During the last few years, radiation using gamma rays, has also been used for the destruction of insect life in foodgrains being carried on conveyor belts.

4. *Cultural control :* The cultural control measures which aim at modifications in the cultural practices for control of insect-pests have been used for over the last 50 years for the destruction of insect-pests. The grape phylloxera which was introduced into France and destroyed about 30 per cent of the vine-yards, was effectively controlled by grafting European grapes to phylloxera resitant root-stocks from eastern U.S.A. Similarly, wooly aphid was controlled by grafting different susceptible varieties of apple to resistant Northern Spy and Majetin. However, during recent years no important development has taken place in this field (cultural control) except by way of putting out new resistant varieties.

Studies on the relationships between insect-pests and their host plants reveal that under natural conditions a high level of resistance may develop in some plants. However, it is absent in cultivated plants for two main reasons :

(1) Crop management tends to destroy the inherent resistance of plant variability by its effort towards plant uniformity.
(2) Man's selection for cropping characters in the husbanded varieties over the uricentes has resulted

in the loss of natural resistance character of plants.

Therefore, through breeding programmes, new efforts are being made to evolve resistant or highly tolerant varieties. Painter (1958) has given a list of some insect-resistant crop varieties being grown in U.S.A. and has discussed how the Hessian fly and European Corn Borer populations have gone down to such low levels with constant use of resistant varieties on a large scale over the years, that in some States, it no longer appears necessary to grow resistant varieties. Recently, varieties of alfalfa, resistant to aphids, have been developed. However, alfalfa plants resistant to the spotted alfalfa aphid are generally susceptibles to the pea aphid. Thus a variety resistant to one pest may be susceptible to another species. The reverse in the case of resistance in a certain sorghums to grasshoppers and chinch bugs, and in certain corn hybrids to European corn borer and corn leaf aphid simultaneously appears to be fortuitous. However, it should not be impossible to combine resistance to two insects. Newer techniques in chemical analysis have helped in identification of chemical bases of resistance in many cases and should result in quicker development of resistant varieties.

5. *Biological control :* The use of natural enemies for the control of pests is not a new idea. Actually, parasites and predators of many insect-pests have been introduced with advantage for the control of certain introduced exotic pests. The activity of locating and introducing new and effective parasites and predators of pest species has increased tremendously during the last 15 years with the establishment of a chain of laboratories all over the world by the Commonwealth Institute of Biological Control. One such laboratory is working actively at Bangalore.

In addition to the traditional method of the use of parasites and predators in the biological control of insects, during recent years the biological control of pests has developed a new dimension, namely, microbial control.

6. *Microbial control :* The study of disease among pests has revealed that viruses, rickettsiae, bacteria, fungi and nematodes cause serious diseases among pests. Some of these pathogens have been intensively studied and techniques

perfrected for their mass production and use in the control of pests. For instance, the Japanese beetle has been largely controlled by using a bacterium, *Bacillus popillae*. Another bacterium, *Bacillus thuringensis* is intensively used for the control of certain lepidopterous larvae. The recent development in microbial control involving use of viruses for controlling the European pine sawfly, cabbage loopers and alfalfa caterpillar are very spectacular.

There are many advantage of the use of microbes over pesticides e.g. no toxicity hazards; no danger to useful insects and no problems of development of resistance.

7. *Chemical control* : The use of chemicals for the control of pests started at least 200 years ago and during the last 25 years, great progress has been made in this method of control. Actually, chemical control measures are used for 85 to 90 per cent of insect-pests in preference over other methods.

(i) *Toxicity hazards* : The pesticides which were used earlier were extremely toxic to man and efforts to find more potent insecticides resulted in the placing on the market of some pesticides which were even more toxic to warm blooded animals than those previously used. For example, DDT was much more effective than the arsenicals which were replaced some 25 years ago and it, in turn, was replaced by endrin for control of several insects. Likewise, ethyl parathion came to be commonly used for controlling another group of insect-pests. As may be seen from the data given below, some of the insecticides like endrin and parathion have a very low LD_{50} value which means that they are extremely toxic to human beings.

	LD_{50} in mg./kg. (Acute toxicity) oral	dermal
DDT	300-500	2,500
Endrin	3-6	60-120
Carbaryl	400	500
Methoxychlor	5,000-7,000	6,000
Trichlorphon	650	2,800
Parathion ethyl	3-6	4-200
Parathion methyl	12-16	67
Malathion	1,400-1,900	4,000

As such, during recent years efforts have been made to find insecticides which have very low mamallian toxicity; for example, carbaryl and methoxychlor which have much lower toxicity to warm blooded animals and can be used for the control of insects which have been hitherto controlled by the application of endrin. Likewise, malathion and other insecticides of organophosphatic origin which are relatively safe for human beings are gradually replacing the more toxic materials like parathion.

(ii) *Phytotoxicity and incompatibility in combination* : The chemicals which were used 30 to 40 years ago,for example, arsenicals, were quite phytotoxic. However, most of the chemicals which have come into the market after the Second World War have no or low phytotoxicity and in several cases, the plant species which are sensitive to certain chemicals have been determined through research programmes; and recommendations are made only for crops on which they are safe.

Incompatibility of insecticides has also been receiving attention because it has been found that when certain pesticides are combined for two different purposes, at least one of the puposes is not served because of incompatibility problem. For instance, recently it has been found that methane-sodium which is widely used in Europe to control soil nematodes and which kills even cyst forming nematodes after stimulating the larvae to emerge from the cyst; does not prove effective in the presence of D-D, a chlorinated hydro-carbon nematicide. There are also various other examples and now as a matter of routine, compatibility charts have been prepared and are being constulted while mixing two different pesticides.

(iii) *Destruction of predators and parasites* : The insecticides which came up first were of general purpose type with a very wide spectrum and killed a variety of insects including parasites and predators. Their use, therefore, resulted in the resurgence of pests. At the same time, certain other insects and mites which were previously kept under check by the natural enemies became pests. This has resulted in recent years in the development of tailor-made highly *selective pesticides*. For instance, Schradan and Menazon are highly selective in killing aphids but do not harm the predators.

Ryania also is selective, killing the codling moth and not its natural enemies.

Dosage adjustments have also been made to avoid mortality of parasites and predators. For example, demeton at 2.5 oz./acre and trichlorphon at 7 oz./acre are effective in the control of spotted alfalfa aphid and do not harm the parasites and predators which are killed by higher dosages.

Insecticides with short persistence, e.g., mevinphos, nicotine, TEPP, oil emulsions, rotenone and trichlorphon are being used more and more to avoid losses of parasite and predator populations.

Strip or skip treatments : Treatment of alternate rows of citrus, spraying 40 ft. wide alternate strips of sugarbeet and strip cutting of alfalfa have proved effective in pest control and at the same time minimized the destruction of parasites and predators.

Resistance in pests to pesticides : Up to 1960, 137 different species had developed resistance to insecticides of every kind—arsenicals, rotenone, pyrethrum, chlorinated hydrocarbons, organophosphates and carbamates, etc. Resistance is induced by : (i) Repeated application of insetcides on a large scale, (ii) a short life-cycle (iii) application of inecticide to relatively closed population which does not mate with fresh individuals from outside. Resistance is developed faster when selection pressure is high, i.e., high degree of mortality occurs. There is some evidence that in some cases the origin of resistance involves protective avoidance, changes in morphology, biological factors, storage mechaisms, etc., but mostly it is due to development of detoxification mechanisms.

The following methods are generally suggested for avoiding or delaying resistance :

(i) Alternate use of 2 or more insecticides of different modes of action; or mixing of 2 insecticides at 1/2 the standard concentration.

(ii) *Use of synergists :* Di (p-chlorophenyl) ethanol (DMC) an acaricide and pipronyl cyclenone increase the toxicity of DDT to resistant houseflies.

Pipronyl butoxide and pipronyl cyclonone are synergists for pyrethrum.

(iii) *Loss of resistance :* Cotton boll weevils have lost resistance to endrin partially after stoppage of use of endrin for 5 to 6 years. However, in many other cases e.g. California red scale resistant to HCN, blue tick in South Africa resistance to arsenicals and citrus thrip resistant to tartar emetic have not reverted to susceptibility inspite of long periods of suspension of spray of the materials to which they have long become resistant.

8. *Inert dust :* The inert dusts which are not chemically active have been used from time immemorial for protection of grain against Bruchids. However, Ebeling at the University of California developed a highly effective inert dust which he called silica aerogel. This was prepared by reacting sodium silicate with sulphuric acid, washing it, drying at high temperature and grinding it into fine particles. These silica aerogels act more by absorption of cuticular fats than by abrasion of the epicuticle. They are in commercial production in USA and are recommended for control of household pests, drywood termites, etc.

New methods of control : During the last decade or so efforts have been made to develop new techniques for the control of insect-pests and I shall now make an effort to describe some of these briefly.

1. *Male sterile technique :* The remarkable and unthought of achievement of eradicating the screw worm fly from Curacao, Florida and many other states of southern U.S.A. by the release of radio-actively sterilized males, has focussed attention on this method. This method has also been used recently and successfully to eradicate the melon fly from the Pacific island of Rota. In this case the population was first greatly reduced by malathion-protein hydrolysate bait. Trails are in progress in the control of boll-worm, boll-weevil, tsetse fly, etc.

The successful use of this technique depends upon a number of factors like :

(i) Knowledge of age of pupae at which sterilization

can be done easily without side affects.

(ii) Production of sterility in males without delecterious effect on longevity and mating competitiveness.

(iii) Ability of released sterilized males to disperse and find the females.

(iv) The female must normally mate only once.

(v) Population density must be naturally low or become reduced by insecticides to a level which makes it possible to release the dominant population of sterile males.

(vi) Sustained release of sterile males which should dominate the natural population of males.

2. *Chemosterilants :* The investigations on chemosilants or chemicals that can render an insect infertile is based on the hypothesis that the mandibulary glands of the queen honeybee secrete a chemical (9-oxodec-trans-2-enoic acid) commonly called the queen inhibiting substance which suppresses the development of ovaries of worker bees. They can be used for :

(a) Sterilizing reared insects for use in male sterile technique, and

(b) Inducing sterility in natural populations, but they are not good insecticides although they can be combined with insecticides. There are two groups of chemosterilants :

1. *Antimetabolities :* Mostly anticancer compounds which function by blocking some enzymes that synthesize nucleic acids which are essential for cell division; e.g. Aphamide, Apholate, Tepa, Metepa. In California, Ebeling developed an antimetabolite for the control of carpet beetle. However, the news that a strain of *Aedes aegypti* has become resistant to apholate is discouraging.

2. *Antibiotics :* Egg laying in the two-spotted mite and the European red mite is inhibited or reduced by very low concentrations of antibiotics (cycloheximide and its derviatives) when sprayed on fruit trees.

Pheromones (*Attractants*) :

(a) *Insect sex attractants** : The field trials with gyplure, the sex attractant in gypsy moth, have shown that the male moths can be attracted into limited area by means of gyplure baited traps where they are killed by insecticides. Recently, Jacobson and colleagues at the USDA Entomology Research Division have identified and synthesized the sex attractant in case of the pink bollworm moths. The sex attractants in American cockroach and many other pests are being investigated for ultimate use in pest control.

(b) *Food attractants* : Food plant selection is determined by 'odd' chemicals i.e., essential oils, glycosides, alkaloids, etc., which guide the insect to its preferred food plant. For instance, mustard oil glycosides attract the cabbage butterfly larvae and the cabbage aphid. However, the bait traps containing chemicals derived from food substances to attract certain insects have not yet been successful. Nevertheless, more work is in progress and entomologists have not lost hope.

Insect hormones : Besides the queen inhibiting hormone of the queen honeybee to which I have made a reference earlier, a number of other insect hormones have been discovered and I would like you to refer to the work of Novak (1966). However, only a few of these, e.g., the juvenile hormone originating from corpora allata, the moulting hormone (which induces moulting) originating from the prothoracic gland, ventral glands and pericardial glands and exohormones, like queen-inhibiting substance, termite-inhibiting substance have any possibility for use in pest control programmes. However, in no case has the knowledge advanced so far as to be of any practical value in pest control programmes.

Advance in technology of pesticide application : During the last five to ten years tremendous progress has been made in pesticide application technology. This has resulted in the development of much finer spraying and dusting equipment for application of pesticides from the ground as well as from the air. The hand or foot operated sprayers are being

*Martin Jacobson, Interscience Publisher, 1965, 154 pp.

replaced very rapidly, in progressive countries as well as in the progressive states like Punjab, by the knap-sack power operated sprayers, which use only five to eight gallons of spray material per acre as compared to 50 to 100 gallons or more required for manually operated equipment.

The aerial spraying has been increasing at a tremendous rate even in India, as can be seen from a steady rise from 19,000 acres treated in 1957 to 85,000 acres in 1963. This does not include the exceptional year of 1962 when 5½ lakh acres were sprayed from the air for the control of pests and diseases in India, out of which almost 4½ lakh acres were sprayed for the control of the locusts.

Aerial spraying : Aeroplanes (Fixed wing, planes and helicopters) have been in use for the application of pesticides for a long time. In advanced countries like, USA & USSR, most of the pest control work is done through aerial spraying or dusting. For a long time the only development achieved in aerial spraying was to reduce the dosage rate to about 25 litres per hectare.

The development of the rotary cage atomizer (the Micro-nair) has brought the droplet size down to 70U MMD (mean mass diameter) from 250U MMD, and opened up new possibilities of ultra low-volume spraying. Spraying every 200 metres at a mean dose of 400 ml./ha., gave good control of locust hoppers, but by 'barrier' spraying (spraying across-wind at intervals at 5 km.) on early instars of the locust with a persistant insecticide in involatile formulation the dosage was reduced to 1.5 litres/sq. km. or 15 ml./ha. Using this new technique 20,000 gln. of 20 per cent dieldrin u.l.v. formulation was sprayed in Rajasthan desert to wipe out the last locust plague in 1962.

For general agriculture, many insecticides like diazinon 95 per cent, phosphamidon 100 per cent, 'Bidrin' 100 per cent and DDT 25 per cent have been tried in South Africa but due to toxicity hazards U.S.D.A. has approved only malathion for spraying by this technique. Some data on u.l.v. as compared to traditional spraying are given below :

		Ultra low volume	*Traditional spraying*
Droplet size (u)	..	80±20	100-300

	Ultra low volume	Traditional spraying
Dosage (l/ha.) ..	0.5-4	25-30
Height (m) ..	5-8	1-2
Swath (m) ..	30	10
Ha/min ..	7.5	2.6
Litres/min ..	3.75	72.8
Deposit (gm) ..	250	750 (On spares vegetation)
Spray volume required for 500 acres (l) ..	250	14,000

Logistics for 500-acre spraying

	u.l.v.	*Traditional spraying*
Spray loads ..	1	28
Loading time ..	3 mts.	1 hr. 37 min.
Ferrying time (10 kg.)	4 mts.	1 hr. 37 min.
Spray time ..	1 hr.	2 hrs. 50 mts.
Turning time ..	1 hr. 39 mts.	4 hrs. 43 mts.

The u.l.v. can lead to considerable economics due to :

1. Redueced cost of application (1/30th in above case)
2. Reduced cost of insecticide due to
   (a) lower application rate, and
   (b) lower transportation and storage costs of concentrates.
3. Smaller number of aeroplanes and pilots required.

Strategy in pest control : The control of pests at first used to be as a curative measure because pesticides were applied only when the pest appeared; and in such cases, it was seen that the pests generally caused much damage before they could be destroyed. This logically resulted in the recommendation of pest control measures as preventive measures. This ultimately resulted in the development of spray schedules which indicated the pesticides to be applied as well as the time of application for avoiding losses due to pests. The spray schedule philosophy implied that a pesticide must be applied at the right time indicated whether or not the pest was present. This meant that spray was some-

times done when it was not really necessary. It was, therefore, an avoidable waste of labour and money and resulted in quicker development of resistence of the pests to pesticides. Subsequently, during the recent years there has been an evolution in pest control strategy towards the development of what is called as *supervised control.* The supervised control implied that some competent extension worker kept a regular record of the pest population in each district and gave a green signal for the application of pesticides as soon as it became necessary in view of the danger of increase in pest population above the economic threshold.

Another important development during recent years in pest control has been a change in the psychology of the pest control operators. Originally the entomologist who advocated the use of biological control was more practical of the use of pesticides. This was because the pesticides used were of a broad spectrum type and caused high mortality among parasites, and predators, as a result of which there was a rapid resurgence of the pest population and new species of insects and mites became pests because of the destruction of natrual enemies which kept their populations at an extremely low level.

It was thus strongly held that the biological control and chemical control methods were strongly opposed to each other and could not be practised simultaneously. However, during recent years it has been realised that, with judicious selection of pesticides and their proper application (low dosage, proper timing, strip treatment, etc.), the chemicals as well as the parasites and predators can be used simultaneously for the control of certain pests. There are other instances, where insect pathogens, parasites and predators have been employed successfully simultaneously and, in addition, other measures like cultural practices (resistant varieties, time of harvesting and method of harvesting, etc.) can be used with great advantage. The use of two or more methods simultaneously is called integrated control.

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Plant Diseases–A Limiting Factor for Crop Production

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1. *Wheat* (*Triticum vulgare*) :

(a) *Bunts* : Bunt diseases are common diseases of wheat. They cause dark bunted kernels instead of healthy grains. In the young stage, the affected kernels give out a foul smell. Dry grains when crushed between the fingers easily turn into black powder and give a characteristic fishy odour. Bunts are caused by *Tilletia caries* (DC) Tul. and *T. foetida* (Wallr.) Liro. In this country, they occur mostly in the hilly regions and, therefore, are commonly called 'Hill bunt'. There is one more bunt caused by a different organism named *Neovossia indica* (Mitra) Mundk., which is found in the plains and is commonly known as the Karnal bunt.

During the last ten years, Hill bunt was observed sporadically in certain parts of Gurdaspur, Jullundur and Ludhiana districts located in the plains of Punjab State. In 1965, in Hansi, near Hissar, Hill bunt appeared in severe form in the cultivator's fields. The cause for this outbreak seemed to be the use of contaminated seed material obtained from some of the hilly areas where wheat was grown. It was observed in artificial infection tests carried out in the Punjab Agricultural University at Hissar campus that conditions

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obtained in the plains are favourable for the appearance of Hill bunt disease. The tests reveal the fact that the so-called hill bunt disease of wheat can also occur in the wheat growing plains provided the inoculum is present. The occasional or sporadic observation of bunt infection in those places may be due to the fact that, for the present at least, there is no local source for bunt inoculum and the disease appears only when infected material from Hills is used. Recently a considerable amount of wheat seed material for breeding and other purposes is being multiplied in the hilly areas of Northern India during summer and the same is being brought down into the plains for sowing in the subsequent winter season. Since bunt infection is quite common in the hilly regions, this large scale seed importation from hills down into plains every year may introduce this serious disease into the plains.

It is, therefore, essential that all such seed material be treated with the suitable seed-dressing agent to eliminate this infection. The seeds are to be treated with fungicides like Agrosan G.N. or Ceresan, just before actual sowing; one part of the fungicide mixed in 400 parts of the seed by weight is the proportion to be used.

(b) *Smuts :* The wheat disease known as loose smut or "Kangiari" causes 20 to 30 per cent approximate losses. This disease reduces wheat grains in the ears to a loose black powder. The causal organism of this disease is *Ustilago nuda.* To prevent the attack of loose smut on wheat plants, the seeds need treatment in the months of May-June when the sunshines directly on the heads and the heat is at a maximum. The seeds to be treated are soaked in ordinary water from 8 a.m. to 12 noon, for four hours. Then they are spread in a thin layer on tarpaulins or thick cloth for drying. The direct heat will kill the mycelium of the organism. After the complete drying, they may be filled in gunny bags and stored for the sowing in next season. This is called solar energy method which is good only for the plains. For the hills where the temperature is low, there is another method to kill the disease organism. In this method, three tubs are filled with water having different temperatures. The first tub contains ordinary water, the second contains water maintained at 52°C while water in the third tub is also kept at 54°C. The seeds to be treated are

held in a gunny or cloth bag and immersed in the first tub for 5 to 6 hours and the bag is then transferred to the second tub where it is kept for 5 minutes. After this, the seeds are transferred to the third tub for 7 minutes. This treatment will kill the disease organisms inside the seeds. This treatment required special attention as the margin of safty is very narrow.

Recently experiments are being conducted to see the effect of some new antibiotics and fungicides which may provide high per cent of control for this important disease.

(c) *Leaf spots :* During the recent years, leaf spots have become a severe problem of wheat. The main symptoms are necrotic blighting of leaves. Spots appear on leaves as soon as the crop is 4 to 6 weeks old. This can become very severe by destroying the foliage at a young stage. The fungi responsible for the leaf spots are many in number and work is still continuing. The causal organism established for blight is *Alternaria triticinia.*

This disease chiefly affects durum varieties of wheat and have been responsible for the failure of several rust resistant varieties. The control suggested is to find source of resistance and test wheat varieties for blight resistance.

2. *Millets :*

(a) *Bajra* (*Pennisetum typhoides*—Staph & Hubb) :

Ergot : Shine and Bhinde (1958) and Mathur (1960) reported ergot (*Claviceps morocephala*) on *bajra* from Maharashtra and Rajasthan, respectively. It was reported that the disease appear in severe form, the infection of ten ranging up to 25 per cent (Bhinde, *et al.*, 1957). Recently it has been observed in Northern India also.

The exact mode of infection by the pathogen in nature is not yet fully-understood. The causal organism *Claviceps microcephala* on infection makes the ear diseased by producing solid, horny structures in place of normal grains which are called ergot. This is reported to be poisonous to pregnant cattle if taken as food; the alkaloid named Ergotin is responsible for this. It can be useful in a way that it has high

medicinal value. Detailed studies are going on.

Smut : This is a common disease caused by fungus.

Tolyposporium penicellariae Bret : The life history of the fungus has been studied in detail by Ajrekar and Likhite in 1933 who showed that the infection is airborne and is immediately followed by sorus production. This has been confirmed by Vasudeva and Iyangar in 1950. Conflicting reports regarding the value of seed treatment are found in literature. It has been claimed that the disease could be controlled by cold water treatment followed by sun drying (Anon. 1950) by ceresan treatment of the seed (Anon. 1949), with hot water and formalin vapour (Mc Rals, 1922) while other workers (Ajrekar, *et al.*, 1933) stated that the seed treatment is ineffective, which appears to be logical considering the mode of infection. Recently Chauhan (1955) has advised a method for assessing the damage due to this smut. Development of this disease under field conditions is yet to be investigated.

(b) *Helminthosporium leaf spot* : A new *helminthosporium* leaf spot of *bajra* caused by *helminthosporium australinse* Bug. has been recently reported from Hissar (Chand, *et al.*, 1966). The fungus initiates small brown spots on the leaves which generally increase in size ultimately covering the entire leaflet often coalescing to form bigger blotches. In severe attack most of the leaves in a plant become infected and the whole plant ultimately dries up. All the approved varieties of *bajra* tested were severely to moderately susceptible.

3. *Jowar* (*Sorghum vulgare* Pers) :

Leaf spots : Recently the leaf spots have become major problem for this crop. There are eight leaf spot diseases caused by various causal organisms.

Amongst the 8 fungi reported to cause leaf spot diseases which have been reported from all parts of India, most are seedborne and practically no work on control measures has been attempted, perhaps because the damage is not severe. Mehta and Bose in 1946 studied the morphology of the fungus *Titaeospora* and *repogonis* whereas Singh *et al.*,

(1951) reported the morphology, etiology and transmission of *Ascochyta* leaf spot.

Rust : The disease is caused by *Puccinia purpuria* Cke. It has become serious in recent years. Premature drying of leaves is reported in certain varieties by Johnston and Mains (1931). Differences in susceptibility were observed in several cultures of sorghum by Soumini in 1949. Further studies in the life history of the fungus and its mode of perpetuation need to be investigated.

4. *Paddy* (*Oryzae sativa*) *:*

Bacterial blight : Bacterial blight of paddy is caused by *Xanthomonas oryzae* (Uyeda and Ishiyama) Dowson. It was only locally important in certain regions of the country in the beginning but, now because the high-yielding rice introducted from Taiwan is susceptible to this disease, it has become very important and requires special attention.

Spraying trials conducted in Maharashtra, and at the central rice research institute, Cuttack, have indicated that the incidence of bacterial blight can be reduced by copper sprayers. The new antibiotic streptocycline has also been found effective for control. They found that seed treatment with this antibiotic and organomercurial fungicide (ceresan wet) plays an important role in keeping down seedborne infection.

The high-yielding variety, Taichung Native-I, is highly susceptible to bacterial blight. They have found that the initial foci of infection and the rate of spread are controlled by spraying with streptocycline at an early date. But the infection spread on this variety very rapidly and conspicuously after flowering even in sprayed plots. However, this type of late infection does not give loss in yield (Padmanabhan, 1966).

5. *Cotton :*

Helminthosporium leaf blight of cotton : A serious disease of cotton, which causes extensive rotting of seed, pre-emergence death of seedlings and defoliation of adult plants was observed for the first time during the month of June,

1966 at the Punjab Agricultural University Farm, Hissar. The disease is caused by *H. spiciferum* (Baim.) Nicot.

First symptoms of the disease are seen when the plants are in the seedling stage. The symptoms manifest as light yellow-chlorotic spots on leaves. During humid weather the lesions on the leaves increase in size and turn dark brown in colour. In case of severe infection, the lesions develop on leaf stalk leading to defoliation. In some cases, lesions also appear on the stem just near the soil level. During favourable conditions (humid weather and high temperature) the stem lesions increase in size encircle the stem and ultimately the whole seedling collapses.

This disease also causes rotting of seeds and pre-emergence deaths of seedlings. In some of the experiments conducted under laboratory conditions, it was observed that as much as 84 per cent of the seed artificially infested with mycelial cultures of *H. spiciferum* failed to germinate.

Most of the cotton varieties except H 14 and 320 F., cultivated in the state are susceptible to the disease. H 14 and 320 F are fairly resistant to the disease. Indications are that treatment of cotton seed with ceresan at the rate of one *chhatak* to 25 kilogram of seed is fairly effective to control the disease.

6. *Gram (Cicer arietinum L)* :

Foot blight : Gram is affected by two major diseases viz., blight and wilt which cause substantial losses in the yield. The first disease is caused by the well-known fungal pathogen known as *Ascochuta rabiei* (Pass). Labrouse has already done a good deal of work on its etiology and control. But so far very little information is available with regard to the gram wilt disease. According to present knowledge, the wilted condition of gram in certain areas is due to *Fusarium aurthoceros* Appel and Wollenwerver. However, there are several areas where no organism could be isolated from the wilted gram plants and as such this type of wilt has been considered as the outcome of certain abnormal soil conditions.

Since this type of wilt is becoming more and more

common, it was necessary to reinvestigate the problem and the results obtained throw some more light on this work. Preliminary surveys indicated that gram wilt is present in several areas of the Punjab Agricultural University Farm, Hissar campus and also in the neighbouring areas. Affected plants occurred in patches in the field. Usually infection ranged from 15-20 per cent but in some fields it was as high as 50 per cent. Such high disease incidence was observed in low lying areas. In the beginning infected plants showed slight yellowing of the leaves, which later-on became more pronounced involving the entire foliage. Ultimately such plants dried completely. Necrotic dark brown patches were often found on the lower parts of the stem of the affected plants but the most typical sign of the disease is the blackening and blighting of the region of the affected plants. Because of this characteristic symptom, it is proposed to call this disease, foot blight of gram. Affected plants produce pods containing only small sized seeds.

Microscopic examination of the blackened foot region of the affected plants revealed the presence of physomycetous mycelium in abundance both in the cortical and pith tissues. Invariably in all such cases, bodies resembling osspores were also observed in these region. Search was made for the conidial stage of this fungus but unfortunately it could not be found.

From this investigation it appears that the wilted condition of gram crop found in Hissar and the neighbouring areas is due to an osspore forming pathogen, probably in the genus *Peronospora*. Further studies are in progress.

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Advances in Plant Disease Control

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When man began cultivating crops 8,000-9,000 years ago, the stage was set for frequent, rapid, and drastic ecological changes. With intensification of agriculture, losses from diseases have increased as the buffering effect of biological controls diminished.

In the words of Stakman (1959), biology is the most fundamentally important science in the world, which is still populated largely by human beings, who are interested in themselves, in their persistence and in their civilization. Biology satisfies the most basic human need, human subsistence. Only a catastrophic food shortage can shock many people into the realization that food production is a biological process carried on by plants and animals under the supervision of practical biologists, commonly known as farmers. Biology is the hope of the world. It is the science that shows how better to sustain life and how to save it, how to produce food, and how to protect against disease. There are eloquent testimonials that diseases were of such great and general concern as to affect attitudes, and modes of thought in some ancient societies and in many modern ones Plant diseases have indeed played an important role in the social development of the world.

Plant pathology has revealed profound and useful truths. It revealed the vast and variable world of micro-organisms and in identifying man's friends and foes amongst them; it has helped to elucidate the role of chemical microelements in the health and disease of plants; it has not only helped man solve many of his most basic problems, but it has helped

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illuminate his intellect and expand his intellectual horizons. Plant pathology has helped to satisfy man's hunger for food and his thirst for knowledge. Plant pathology is one of the sciences whose greatest appeal to the public lies in its utility.

As put by Harrar (1959), in the years ahead science and technology will have to reach unprecedented heights of efficiency if we are to preserve any semblance of reasonable standards of living during the next century. The role of plant pathology in this effort is an important one if future generations are to be adequately supplied with food and other agricultural commodities necessary to an enlarging population. An intimate alliance of the fields of biology, chemistry, physics, engineering and economics has resulted in doubled, trebled and even quadrupled average yields of major crop plants with commensurate improvements in quality. Unfortunately, however, there are many areas in the world that are relatively unaffected by modern technology, with the result that in these areas agricultural practices are still primitive, yields are low, a high fraction of the labour force is required for food production, and economic and social progress is retarded.

It is the obligation of plant pathologists everywhere to recognize that they have roles in both the national and international scene with respect to plant disease control. Their individual and concerted efforts through their institutions and professional organizations should form the foundations of a sound plant protection programme.

Many landmarks have been established in the realm of scientific agriculture during the past century. None of these rises more prominently on the plains of human endeavour than those that mark the forward progress in controlling plant disease by chemicals (McNew, 1959). The new "insoluble coppers" include compounds like tribasic copper sulphate, copper oxychloride, cuprous oxide and copper phosphate. The first three of these are only used on a large scale at present either as dusts or as water miscible spray formulations.

The inorganic mercury compounds have been replaced by organo-mercury compounds which have found favour as seed disinfectants and protectants and we also found useful

for the control of apple scab and rice blast, and the treatment of soil-borne diseases in vegetables, sugarcane and rubber (in Ceylon) (Ramakrishanan, 1961).

Several organic fungicides, carbamates, quinones and phenols, have replaced copper and mercury compounds and have a wide range of uses. These fungicides include captan, thiram, ziram, zineb, nabam, and maneb. The advance in the knowledge of the mode of action of these chemicals on fungi has led to the formulations of new compounds possessing greater and more persistent protective effects. The modern tendency is for compounds having specific use than for those having a wide range of use. The idea of designing a molecule to fit a particular need in plant protection has crept into plant pathology. Safer fungicides that will protect plants without jeopardizing their growth and health have been designed to operate as nabam, where an essentially inert material generates the toxicant as it is needed without overburdening the plant with it. The principles of how to design molecules for specific attributes are rapidly being established. New systemic fungicides have been developed and are under tests in USA, England and Germany (McNew, 1959). Formulations of organic nematicides and soil-fungicides like mylone and vapam are also coming into use.

Certain antibiotics have been employed and found useful as systemic fungicides or bactericides, such as streptomycin, and it has been claimed that fire-blight of pears, bean blight and canker of citrus are controlled by their use. Actidione and anisomycin have been used for controlling powdery mildews and bean rust respectively. Griseofulvin has also been found to be useful. Recently, in India, streptocyclin and aureofugin have been found to be effective for the control of bacterial blight of rice and some fungal diseases, respectively. In Punjab, aureofungin soak has given good promise for the control of internally seed-borne mycelium of loose smut of wheat (Goodman, 1962, Ramakrishnan, 1961). It is obvious that a new era is about to begin on the horizon of plant chemotherapy (McNew, 1959).

Oil-based fungicides and, sometimes oil alone, have been applied on a large scale in banana plantations for the control of some banana diseases. Oil-based copper oxychloride

has been found to give remarkable success for the control of rubber diseases in South India, as a low-volume spray.

Control of virus diseases is receiving greater attention in biological laboratories (Vasudeva, 1959). The serology of plant viruses has now developed into an important branch of virus study. It is possible to differentiate virus strains by the use of serological reactions. Also serological reactions help in the quantitative assay of viruses during multiplication or inactivation. Most important of all, the serological reactions are being employed for the quick detection of viruses in certain crop plants and in ensuring their freedom from virus infection and thus helping to establish virus-free stock (Wetter, 1965).

New and more potent vectors of virus diseases, such as nematodes, fungi, mealy bugs and mites have been established, and the knowledge of the relationship of viruses and their vectors has helped to control some viruses effectively.

The recent introduction of the systemic fungicides has opened new opportunities for the direct control of insect vectors.

Although heat and chemotherapeutic treatments have been effectively used for the control of certain stone-fruit viruses, the only method of combating such diseases is the production of a virus-free nursery stock and its distribution under a recognised system of certification. Citrus decline caused by tristeza, psorosis, xyloporosis and 'greening virus', also requires similar attention and active field of research is envisaged to develop tolerant stock-scion combinations and develop a bud-wood certification programme for the control of this group of viruses (Hollings, 1965).

In the matter of growing varieties resistant to plant diseases in India, outstanding success has only been achieved in the case of varieties of cotton resistant to wilt; of sugarcane to red rot; of linseed to rust; of wheat to one or more rusts; of paddy to blast; and of interspecific hybrids of coffee to rust (Mehta, 1963; Walker, 1965).

In India, systematic work on the breeding of rust-resistant wheats was started by Pal in 1935 in collaboration

with Mehta and several rust tolerant varieties have by now been released for general cultivation (Parsada, 1960). In recent years, interest has developed in evolving suitable fungicides and zineb formulations have been found to be effective, although wide-scale applications may still not be possible in the field. Some of the Mexican wheats, viz., PV 18, Kalyan 227 developed in Punjab are highly resistant to rusts and are also high-yielding. Such wheats have a great future in India. Some wild species of *Abelmoschus* have been utilized for developing resistant *bhindi* (*Abelmoschus esculentus*) for the control of yellow vein mosaic.

The study of phyllosphere in relation to plant disease control is a new field of investigation in plant pathology (Sinha, 1965), and bacterial cultures have been isolated as epiphytes which inhibit the development of some leaf-spotting fungi. Epiphytic resident bacteria play an important role in the germination of fungal spores (Leben, 1965).

Attempts to control fungal diseases of plants through hyperparasitism have met with very little success (Boosalis, 1964). The study of soil microflora and soil fungistatis has revealed that this field of research is promising to control some of the soil-borne pathogens especially those causing root rot, wilts, damping off and some success has been achieved (Lockwood, 1964).

Plant disease therapy with the use of bacteriophages against bacterial pathogens, has been successful against a few bacterial pathogens but field scale application has not been possible due to certain obstacles (Okabe and Gots, 1963).

Intensive research at the various Central Institutes and State Sugarcane Research Stations in India, on some of the major diseases of sugarcane like red rot, wilt, mosaic, have yielded encouraging results and measures to control them have become available. Research on other maladies of sugarcane due to viruses, fungi, bacteria and flowering parasites, some of which have been reported in recent years from India and have assumed major importance, is in progress and measures to control them will become available soon (Chona, 1958).

The role of plant disease survey in forecasting plant

diseases has not yet been developed in India because of the lack of information of the effect of environment on plant disease and the pathogen under field conditions, although this aid in plant disease control is well-developed in USA and England (Miller and o' Brien, 1954).

The role of therapy in plant disease control is now-well-established, such as, control of disease of tea in North-East India (Agnihothrudu, 1963), radiation therapy in the control of many plant diseases (Bajaj, 1963), Chemotherapy against many plant diseases (Horsfall, 1963; Raychaudhuri and Mishra 1963; Mathur, 1963) thermotherapy against virus diseases (Nagaich, 1963), the use of antibiotics in plant disease control (Rangaswami, 1963), chemotherapy against loose smut of wheat (Gera, *et al.*, 1963), and seed infections (Suryanarayana, 1963), therapeutic control of stem-gall of coriander (Gupta and Sinha, 1963), therapeutic control of rice diseases (Padmanabhan, 1963), and chemotherapeutic control of plant nematode diseases (Raski, 1963, Dimond, 1965).

Host-parasite relationship studies in plant diseases have also yielded considerable information which has been utilized for control of many plant diseases such as wilts caused by bacteria and fungi, rusts, foot rots, *helminthosporium* leaf spots, and plant nematodes (Anonymous, 1964).

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Crop Diseases—Their Nature And Causes

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Crops are subject to many diseases which cause enormous economic losses throughout the world. There are about 100,000 distinct plant diseases, of which about 20 per cent are fairly destructive. The tomato alone is attacked by 83 fungus, 16 virus, and 11 bacterial species. However, only a few plant diseases occur regularly and inflict extensive damage in spite of the adoption of various control measures. Rusts alone have been reported to cause an annual loss of about 500 million rupees in India. It would not be an exaggeration to say that 10-15 per cent of crops in India are destroyed by disease every year. If timely measures could be adopted to prevent such heavy losses, it would certainly result in increased production and perhaps the country could cover the national food deficit in no time at all. This points out to the need for increased research in this direction.

Diseases of crop plants cause damage in various ways. They may suppress chlorophyll content, reduce the leaf area, curb the movement of solutes and water through the stem, reduce the water procuring capacity of the roots, supress translocation of food-stuffs away from the leaves or may promote wasteful use of products of photosynthesis by encouraging abnormal respiratory activity. In short the disease may cause abnormal metabolic functioning of plant parts. Environment plays an important role in the initiation and further spread of disease-inciting-pathogens in the plants. In fact, the losses due to diseases, depend upon the prevalence of such environments as act on host-pathogen

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inter-action in favour of the pathogen.

The common symptoms produced by diseases are of three general kinds : necrosis, hypoplasia and hypertrophy; whereas necrosis causes rotting and decay of tissues, hypoplasia results in under-development of tissues while hypertrophy leads to abnormal overgrowth. The injury and abnormal growth in diseased plants is mainly caused by the enzymes secreted by plant parasites singly or in association with the host tissues. For example, the vascular fusaria initiate disease by production of pectolytic enzymes in the xylem which hydrolyze the pectic materials in host-cell walls, resulting in the formation of plugs containing pectic material in xylem vessels. In case of virus diseases, the hereditary mechanism of the host controlled by its deoxynucleic acid (DNA) is disturbed by the ribonucleic acid (RNA) of the virus. The intrusion of new nucleic acid into a host cell causes changes in the nucleic acid synthesis, which in turn, leads to a new pattern of protein synthesis, culminating generally in the formation of a new virus. The disturbance in nucleoprotein synthesis imposes stress and strain on the normal functioning of cells and this leads to their abnormal functionig.

Most of the disease-inciting agents spend a major portion of their lives as saprophytes on decaying organic matter in the soil. During favourable periods they may live as vegetative bodies, actively dividing bacterial cells or larval stages of nematodes; however, during adverse periods fungi exist in forms of sclerotia, spores or rhizomorphs, and most of the nematodes become encysted. Bacterial pathogens, with the exception of a few, do not produce spores. They tide over the unfavourable conditions in stem cankers on seed tissues. Most of the facultative parasites are weak parasites and attack plants more or less by chance when they come in contact with a wound or find the host tissue in a juvenile condition that is easily susceptible to invasion.

Under natural conditions, the selection and competition phenomena come into play, resulting in a sort of biological balance between hosts and parasites. Due to these factors, the host is frequently injured but not wiped out. In modern agriculture, however, when new and improved varieties are being introduced at an increasing rate, the biological

balance between hosts and parasites is disturbed. We are constantly bringing together new plant pathogens and hosts which have not yet gone through the evolutionary processes of becoming adjusted to each other. This can lead to very grave results. There are numerous examples in the literature where crops have been devastated by the importation of a foreign pathogen into an established population of plants or by the introduction of a new crop or crop variety into an area. The intoduction of new durum varieties of wheat in the Dakotas and Minnesota resulted in the severe stem rust epidemic of 1953 and 1954. The rust destroyed 75 per cent of the durum and close to 30 per cent of the bread wheat. There is another classic example which illustrates how the unintentional introduction of new pathogen in a locality can result in wholesale destruction. The chestnut blight fungus was introduced into the United States from the orient before 1900 and soon a valuable forest free was wiped out. Nothing remains today of the great chestnut forests of the Eastern United States but bare branches of dead trees. Recently, a new bacterial pathogen has been introduced in India along with rice variety, Taichung Native-I. It incites bacterial blight on rice, which is a very destructive disease. If timely measures to control the disease are not taken now, it may possibly jeoparadize the cultivation of rice in India. Similarly a new disease on cotton incited by *Helminthosporium spiciferum* has recently been noticed. It causes pre-and post-emergence deaths of seedlings. Probably the new species of the *Helminthosporium* has been introduced in India along with some foreign breeding material.

The breeding technique involving the introduction of a new gene for resistance to a particular disease into a variety to induce resistance, may have dangerous potentialities sometimes. For example, for breeding oats resistant to crown rust, genes were introduced from the variety *Victoria* for a hypersensitive type of resistance. Although a rust resistant variety was produced, it was extremely susceptible to a second rate pathogen which has since been named *Helminthosporium victoriae*. *Helminthosporium* blight built up to such proportions within five years that it forced the farmers to quit growing Victoria-derived varieties and to turn to other sources of resistance. Diseases are, in fact, shifting enemies. Therefore, as far as possible, every care should be taken to preserve the biological balance between host and pathogens

evolved through evolutionary processes.

The causes of disease : The causes of diaseases are many but they fall into two main groups, parasitic and non-parasitic. In the parasitic groups, are diseases caused by fungi (8,000 or more species), bacteria (about 170 species), nematodes (about 200 species) and viruses (about 300 major representatives). The parasitic organisms attack plants, obtain food for their existence and thereby disturb the normal metabolism of the plant. In the non-parasitic group are included those diseases which are caused by unfavourable growing conditions. Deficiencies, excesses or improper balance of elements essential to plant growth fall in this category.

The fungus diseases : Fungi are a lower form of plant life. They lack chlorophyll. Consequently, like higher plants, they cannot manufacture their own food from Co_2, water and minerals. For their existence, they either obtain food from dead organic matter or from other living forms. Those that feed on other living organisms are known as parasites and the organisms attacked are called hosts. Such an attack on the host causes a disturbance which we recognise as a disease. In most of the fungi, the mycelium is haploid, though in quite a few, it is diploid or dikaryotic.

Most of the fungi produce spores, which vary in shape, size, colour and method of production. Some types of spores are produced at the ends of specialized branches of hyphae, while others are produced in complex fruiting bodies. Many fungi produce more than one kind of spore, which are disseminated by air currents, water, insects, and other agencies. If they happen to fall on a susceptible plant when environmental conditions are favourable, infection is likely to occur and the plant becomes diseased.

Some of the important crop diseases which are incited by fungi are smuts, rusts, mildews, blights and wilts, etc. All these diseases cause heavy losses to crops at one time or other.

The bacterial diseases : Bacteria are microscopic, single-celled organisms. Relatively few bacteria are capable of causing plant diseases. The pathogenic bacteria belong

to the genera, *Pseudomonas*, *Xanthomonas*, *Bacterium*, *Frawinia*, *Agrobacterium* and *Corynebacterium*. Most of them are gramnegative rods that are very sensitive to sunlight and desiccation and so they are not dispersed readily by air currents. They multiply at a very great speed by binary fission. It has been estimated, that given an adequate food supply and favourable condtions of moisture and temperature a single cell can give rise to 17 million cells within 12 hours. They enter plants through wounds, stomates and hydathodes on leaves, lenticels on woody stems and nectaries in the flowers.

The important types of diseases caused by bacteria are soft rot, leaf spot, vascular diseases, bacterial galls and extensive blights.

The virus diseases : Viruses are ultra-microscopic entities, visible only through the electron microscope and can produce disease in plants. Viruses are nucleo-proteins of high molecular weight and are produced readily in the living cells of the host. The virus particles may be straight or flexuous rods, spheres or polyhedral bodies. Virus diseases of plants exhibit a variety of symptoms. The most common evidence of diseases expressed in the green lesions of higher plants is the alteration in the usual development of chlorophyll. The other effects of viruses which are exhibited on plant tissues are vein-clearing, veinbanding, ring spots, necrosis, stunting, malformation and over-growth. Viruses are transmitted from plant to plant by mechanical methods like rubbing or injecting infectious juice from diseased plants, by grafting diseased tissues on healthy plants, by seed or other organs, by insects, by parasitic phanerogams and by soil.

The nematode diseases : The nematodes are eelworms that live in the soil or water. There are about 500 different species of plant parasitic nematodes. The damage through nematodes is particularly serious in subtropical, tropical and mild-temperate climates because of the longer growing seasons and continuous growth of crops.

Among the more destructive nematode diseases, the root-knots caused by several species of *Meloidogyne* are most important. The young female nematode penetrates

the rapidly growing root and locates in cells near the tracheal and phloem tissue. Secretions released during the feeding operation apparently lead to dissolution of cell walls, stimulation of protoplasmic growth, and increased division in the vicinity of the nematode head. This results in the formation of a composite cell with hundreds of nuclei. Eventually the infested roots decompose and release eggs into the soil and these produce a new generation of larvae.

The parasitic seed plants : The diseases caused by parasitic seed plants are manifested by three mechanisms, viz., direct parasitism, epiphytic habitat and destructive competition to nearby associates.

The commonly recognised parasitic higher plants are dodder (*cuscuta* sp.), witchweed (*striga* sp.), and broomrape (*robanche* sp.).

The physiogenetic diseases : Physiogenic diseases are caused by abnormal fluctuation in the environment of crop plants necessary for their normal development. Excess or deficiency in essential environs like soil moisture, temperature, nutrients in the soil, etc., lead to physiogenic diseases. Besides defective physical soil conditions, faulty agricultural practices, high velocity winds, torrential rains, frost, snow and industrial bi-products like, smoke, smelter, gases and dusts from cement plants, etc. etc., may also be the causes of physiogenic disease. The economic losses caused by this group of diseases to our crops are much more than one imagines. Some of the important diseases like water-core of apple, sunscald of vegetables, heat canker of flax, freezing injury to vegetables, black-heart of potato, internal necrosis of plants, etc., are the direct results of destructive physiogenic causes.

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Microbes as Potential Sources of Protein

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The protein problem will have world-wide recognition by the year 2,000 when the present world population of three billion is almost doubled. In 1958, the total world production of animal proteins was about 20 million tons of which 14 million tons were consumed by the less than one billion population of the advanced countries and the rest by the two billion inhabitants of the under-developed countries. Consequently, the production of high protein should be raised three times in order to adequately feed the then expected population of over 6 billions.

Scrimshaw & Behar (1961) stated that approximately two-thirds of the world population is already suffering from a protein deficiency disease known as *Kwashiorkor*. Moreover, Yoshioka (1963) documented this problem with a sobering example when he reported that every other baby born in Central Africa dies before the age of five as a result of protein deficiency. In these areas, carbohydrate foods are abundant but protein sources are either costly or unavailable, and the area people are *eating but still starving*. This problem is still more serious in India where there is already a shortage of carbohydrates. Sukhatme (1965) has pointed out that the incidence of malnutrition in India is at least 50 per cent and the incidence of *Kwashiorkor* disease is also very common.

At present roughly more than half of the poeple of India have a poorly balanced diet that retards normal growth. Their diet lacks mainly in animal protein. They live

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principally on grains, tubers, and little pulses which may supply enough calories but which contain inferior protein lacking in certain amino-acids that are present only in animal proteins. Under the present conditions of expanding population and limited resources of agriculture, Indians cannot afford to get animal proteins like the people in Europe and North America.

Now there is a big question. How are we going to meet the ever expanding demand of protein ? There are extremely broad possibilities inherent in the study of the synthetic activities of microbex. In some cases, microbes are replacing the higher plants as sources of various substances. This is true for the manufacture of enzyme preparations, vitamins, and organic acids. In the future, it is quite possible that microorganisms will be found to be more profitable producers of proteins, fats, and carbohydrates than are the cultivated higher plants. The cultivation of industrial microbes depends completely and exclusively on human will, while agriculture depends upon uncontrollable natural vagaries. The relative rates of production of protein by various organisms have been compared in the following table :

Organism	*Protein production per day*
500 kg. beef animal	.. 0.4 kg.
500 kg. soybean	.. 50 kg.
500 kg. yeast or filamentous fungi	.. 50,000 kg.
500 kg. bacteria	.. 50,000,000,000,000kg.

Source of microbial protein : Keeping in view the great potentialities of microbes for the production of protein, various plans are in progress in the world to increase the world protein production.

1. *Algae :* Because of their autotrophic mode of nutrition, algae have been regarded, for a long time, as a potential and important source of food for the ever increasing propulations. The use of green algae or their value as photosynthetic gas exchangers as well as food on prolonged space voyages has also been emphasized. The principle requirements for mass culture operations include the provision of a suitable nutrient medium, a proper temperature, an

adequate light source, stirring sufficient to reduce local depletion of nutrient elements to a minimum, and an organism adapted to culture conditions. The most popular algal genus used is *Chlorella*.

Once an algal mass is produced, it becomes a problem to make use of it as a source of food. I5 has been shown that the cell wall of *Chlorella* is quite resistant to breakdown. It is composed of difficult-to-digest cellulose. Many atempts to render this resistant material usable have been reported. In some cases, cooking the algal masses has met with some success. In other cases, enzymatic degradation has been used to effect break-down, using celulases and pectinases found in organisms such as snails (*Helix pomatia*) and fungi (*Myrothecium verrucaria*).

In any event, once the algal cells have been digested, it has been revealed that these may not provide as complete protein as could be desired. Inspite of their high protein content and good calorific value, *Chlorella* cells are low in amino acids such as methionine, histidine and tryptophan. Investigations with *Scenedesumus obliquus* (another alga) reveal that protein from this source is quite satisfactory as a foodstuff. While discussing the acceptability of microbial food, Bunker (1963) has pointed out the tightening the back of throat ("gag factor"), unpleasant after taste, hard digestibility, diorrhea and gastro-intestinal troubles from eating *Chlorella*. Its production is also not economical at present.

2. *Bacteria :* Recently bacteria (*Escherichia coli*) have been grown on a substrate of petroleum hydrocarbons as an energy source plus cheap inorganic nitrogen. This is still in experimentation and nothing can be said about its future. Ogur (1966) has pointed out that though the protein content of bacteria is very high, yet there are many problems based upon bilogical value arising from low content of particular amino acids and from low lipids or carbohydrates. It also involves poor digestibility or even possible toxicity when bacteria are used as a source of complete foodstuff.

3. *Protozoa :* The culturing of protozoa on massive scale is in progress in Russia and sufficient quantities have been produced to conduct feeding trials with humans, which yielded results indicating that protozoan protein may be

accepted for use as human food in the near future (Genin & Shepler, 1964).

4. *Yeast* : Yeast (*Torulopsis utilis*) can be grown with inorganic nitrogen on a large variety of inexpensive sources of carbohydrate such as mollases, sulfite waste liquer from paper plants and other wastes of fruit, vegetables, dairy and forest industries. A yield of approximately 50 per cent of dry yeast containing about half the protein can be expected on the basis of the sugar fed. Considerable thought was given to the utilization of brewer's yeast as feed or food but still it continues to be limited by the fact that it is not competitive in price with other available protein concentrates and its slightly bitter taste. Moreover, Carter and Phillips (1944) have pointed out that when yeast is debittered, to render it palatable, some of the vitamin content is lost.

5. *Filamentous fungi* : Keeping in mind all the limited resources of protein and vast quantities of carbohydrates in the world, Dr. William D. Gray initiated on April 4, 1960 in the Mycelogy laboratories of the Ohio State University a long term program designed to explore the potential of a very large group of filamentous fungi known as the Fungi Imperfecti, as possible sources of edible protein. The program has proceeded without interruption until the present date, but now the center of activity has been transferred to the Southern Illinois University since September 1964. The group Fungi Imperfecti was selected for such studies because of their ubiquity and rapidity with which many will grow and almost limitless choice of test organisms may be made from this group, since it comprises about 20,000 form-species, distributed through more than, 1,3000 form-genera.

The first step in this program was to establish criteria of acceptability on the basis of which it could be determined whether or not a particular test organism could be judged to have the potential which would warrant its further more thorough investigation. These criteria were as follow :

1. The organism must be capable of growing on a medium with an inorganic nitrogen salt as the sole source of nitrogen.
2. It must be able to grow in submerged aerated culture.
3. It must efficiently convert substrate carbon to tissue

carbon and at the same time accomplish a near theoretical conversion of inorganic nitrogen to organic nitrogen.

4. It must grow rapidly. Four days have been set arbitrarily as the maximum permissible length of time for the growth period.

When a fungus has met the above four criteria, a definite program is established to attempt to improve yield up to the point where further increase does not seem possible. In his initial screening experiment, 38 forms were tested and of these, 36 were capable of utilizing nitrogen from inorganic salts. While most of the experiments were conducted with small shake flask cultures, judgement of whether or not a fungus can grow in submerged culture was based upon its behaviour in 6-liter cultures in large carboys fitted with aeration devices. The majority of the different forms tested in this manner grew well, although some grew very slowly, and a few apparently could not grow at all under such conditions. Now the work has progressed to the extent that in several instances 150-liter cultures have been grown successfully in a 250-liter pilot plant fermenter. In his initial studies, the best results were obtained with *Heterocephalum aurantiacum*, which, in a 4-day period consistently yielded 1 lb. of dried mycelium per 1.8 lb. of sugar utilized. The crude protein content was as high as 35 per cent which is the same as that of dried chipped beef, the meat product of highest protein content.

Although the initial studies were conducted in a medium in which the carbohydrate source was dextrose, it was soon realized that if any major contribution was to be made to the world, protein pool using fungi as the agent of biosynthesis, the carbohydrate used in any region would have to be the one produced in great quantity and most available in that area. Thus, Dr. Gray and his associates turned to different crude carbohydrate sources such as sweet-potatoes, potatoes, corn, rice, cassva root, cassva flour, citrus molasses, cane mollases, beet molasses, whole sugar-beets, beet shreds, and wood flour. To date, the best results based on total crude protein per liter of medium have been obtained with sweet-potatoes, corn, rice cassva, root, cassva flower, citrus molasses, cane molasses, beet molasses, whole sugar-beets and beet shreds as the carbohydrate sources.

Dr. H. J. Bunker, consultant in Industrial Microbiology, Twickinham, England has pointed out that there is critically an inexhaustible supply of carbohydrates material (mainly cellulose) from plants but it cannot be used directly for conversion into protein by fungi as it requires prehydrolysis before it is used as a substrate. Keeping in view the shortage of edible carbohydrates in India, Chahal (1966, 1967) turned to use wood, a cheap and abundant source of carbohydrate, for its conversion into fungal protein. Experiments conducted by him have over-come the hurdle pointed out by Bunker. New synthesis of fungal protein, by growing cellulolytic fungi directly on wood pulp, has opened a new era in this particular field. The results obtained by him have indicated that industrial wastes with high cellulose material like sugarcane baggasse, rice husk, etc., can be good substrates for conversion into fungal protein.

Thatcher (1954) gives sources of opinions on the nutritive value of fungal mycelium for human food, from which it appears that in war-time, people given dried mycelium of *Fusarium*, *Candida* and *Rhizopus* were in better health than others not fed these supplements. Chastukhin, *et al.* (1956) has reported that beneficial effect on the growth of animals was achieved by the addition of a number of filamentous fungi to fodder ration. Gray (1962 b) has shown from his preliminary feeding trials that adult mice can maintain their weight when fed on a diet consisting wholly of dried mycelium of *Heterocephalum aurantiacum*.

Although there are reports that fungal mycelia contain all the essential amino-acids (Takata, 1929) and even contain high concentrations of certain amino-acids like cystine and methionine (Thatcher, 1954), there are also other reports of deficiency of cystine or methionine (Skinnes and Muller, 1940). The work of Hughes (1956) illustrates that diffrent fungus proteins differ with respect to their amino-acid proportions, and the earlier work of Stokes and Gunness (1946) illustrates that amino-acids proportions may be altered by altering certain factors in the environment.

Gray and his associates have shown that the fungal protein is tasteless, odourless, and colourless and contains all the essential amino-acids. This could be used as such or mixed with other food stuffs. Since most Indians are

vegetarians and sources of plant proteins are limited, the scope for research work on fungal protein in India is unlimited.

Recently Chahal and his associates (1968 & 1969) have reported that out of 44 different cellulotytic fungi only four, viz., *Myrothecium verrucaria*, *Chaetomium globosum*, *Rhizoctonia solani* and *Trichoderma* sp., were able to grow well on cellulose (wood pulp) and produced maximum amount of fungal protein. *R. solani* surpassed all the test fungi in respect of total protein production. Cellulose was converted into fungal mycelium containing 23 per cent protein and 7.5 per cent fat. The protein and fat content of this fungal food is more than that of any cereals used as a staple-food. The qualitative analysis of amino-acid content of the mycelium, thus obtained, indicated the presence of 20 amino-acids. All the essential amino-acids were present but the presence of thiriomine was doubtful.

The fungal product from *R. solani* is of cream colour, have a slight mushroom odour and is tasteless. Biological and nutritional value will be worked out before it is recommended as food for humans or feed for animals.

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Towards Nutritionally Adequate Diet

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According to a recent document of the Food and Agriculture organisation of the United Nations, some 60 per cent of the people in the underdeveloped countries comprising some two-thirds of the world population suffer from under-nutrition or malnutrition or both. Undernourishment in general refers to inadequate intake of energy in terms of calories, while malnutrition may result from many and varied nutrtional imbalances or deficienceies.

Most of the developing countries are loosing the capacity to feed themselves because per capita food production fails to keep pace with population growth. One problem is that of a diet deficit. Another is that these countries have serious nutrition problem which are jeoparadizing their future. In India the problem is severe at both these fronts. To bring a better future balance between population and food supplies the following measures are being taken :

(1) a vigorous family planning programme to reduce the rate of population growth; (2) increased agricultural production through the use of technology and education. It is hoped that as a result of our vigorous birth control programmes, the rate of population growth may begin to decline during the next few decades. But an important fact to be realised is that only well-fed and healthy children can grow and learn to the maximum extent of their genetic potential and only well-nourished and healthy adults can be fully productive members of society. The idea of family planning cannot be completely sold to the people unless children conceived have a good chance of survival.

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It has been clearly indicated by studies of Cravioto (1966) that an early retardation in physical growth and development may be accompanied by permanent limitations in later learning and behaviour. The degree of malnutrition responsible for retarded growth also increases susceptibility to infection. Most of the high mortality attributed to diarrhl diseases, measles, tuberculosis and other infections is really due to a synergism of infection and malnutrition (Scrimshaw, 1965, and 1966). An infection in an already malnourished individual frequently precipitates frank and even fatal nutritional diseases (Scrimshaw and Behar, 1961).

Need for protein : Protein malnutrition probably is the foremost public health problem. Protein deficiency particularly affects young children and pregnant or feeding mothers. The most frequent and often fatal disease caused by a deficiency of protein relative to calories is Kwashiorkor. Nutritional marasmus is also common among young children soon after weaning. In adults lack of protein leads to apathy and lethargy. The nutritive value of dietary protein depends as much on its quality as the total amount present. The best sources of the high quality proteins are foods of animal origin, i.e., meat, milk and egg products. But it has been estimated that 70 per cent of the world, supply of human dietary protein comes from vegetable sources and 30 per cent from animal sources. In India, with a majority of vegetarian population animal sources supply only 12 per cent of the total protein against 70 per cent in the United States.

Protective nutritional elements : Deficiencies of iron and B-complex vitamins make anemias of nutritional origin widespread and the nutritional anemias are responsible for much-lessened vitality and productivity. A deficiency of vitamin A is another important cause of increased deaths from infection, as well as of blindness. A vitaminosis A is endemic in India. A deficiency of vitamin C causes the disease Pellagra.

In diet-deficit areas, adults adapt to chronic shortages of calories as well as to anemia by reduced activity. Thus a man may be weak and unable to produce to capacity, but continue to live on an inadequate diet without protest. It is easy for middle and upper income Indians from fortunate areas like Punjab to consider people from relatively un-

fortunate areas as lazy and without ambition when they actually need more and better food.

Remedial measures at state or national level : In addition to conventional protein sources like cereals, pulses and some vegetables, it is appropriate to consider unconventional ways also. Since these new methods need centralized action there has to be a planning at higher levels. This planning call for thinking on the following lines :

(1) *Cropping pattern for production of maximum nutrients per unit area :* The production of nutrients per hectare by major crops grown in India are presented in Table 1. The calculations of nutrients per hectare have been made with average Punjab yields From an individual or a family point of view the nutrients per unit weight of foodstuff are important. But for the planning of satisfactory diets at state and national level it is important to get maximum nutrients out of fixed land resources. For example compare potatoes with wheat. With average yields per hectare potatoes produce 2½ times as many calories, 1.2 times as much protein, 2½ times as much minerals, seven times as much vitamin A, two times as much vitamin B and hundreds of times as much vitamin C.

Similarly sweet-potato, ranks quite high in calories and minerals. Carrots are high in minerals, vitamin A and vitamin B. Spinach is an excellent source of minerals, vitamin A and vitamin C. Tomato is a top producer of vitamin C per hectare. These calculation of nutrients per hectare are intended to show that there are conspicuous differences in nutrient yields per hectare. With land as a limiting factor in one country, cropping adjustments with a view to getting maximum nutrients should be given a serious consideration. This would involve changing the eating habits of people and many may say this cannot be done. However, we have learnt to eat tomatoes and drink Coca Cola which were almost unknown when I was young.

2. *Improvement of existing crop plants for better nutritional values :* The genes Flory two and opaque two have been discovered which double the protein quality of maize. If similar genes can be found for wheat and other cereals, there can be significant increase in protein production on existing

land. Of course, we can also improve the protein quality of cereal grains through the appropriate addition of synthetic amino-acid and there is a strong case for doing so for cereal-eating populations of India whose animal protein sources are not adequate. In an effort to increase the vitamin contents in various vegetable crops very commendable achievements have been made. The vitamin A content has been tripled in some of the new sweet-potato varieties. Cabbage breeders have increased the vitamin C in that crop by many times. Similarly in potato vitamin C has been greatly increased. Efforts are in progress to improve total solids in potato, with a maximum goal of 18 per cent in carbohydrate content. Even in the case of our melons vitamin A can be tremendously increased by breeding yellow flesh in our present varieties.

3. *Oilseed meals :* The press cake remaining after the oil is extracted from soyabeans, cotton-seed, groundnut sesame and other oil-rich seeds contain about 50 per cent protein of relatively good biological value. Oilseed meals can be ground finely and mixed with two-third cereal grains to provide a mixture which meets the full protein needs of both children and adults. When cooked as a thick gruel, each glass of the mixture can provide the same amount of protein and a better complement of essential nutrients than a glass of milk, at one-fifth the cost.

Several U.S. companies have developed processes for extracting protein in pure form from the oilseed meals, spinning it like nylon into fibres of desired size and texture and combining these fires into accurate simulations of the texture of chicken, ham, bacon an other foods. Such preparations can be eaten vegetarian chicken, ham, steak etc.

A soft drink prepared from soyabean has found great favour with people in Hong Kong. Similar nutritive drinks can go a long way in improving the diet of Indian people who consume lot of drinks in hot weather.

Groundnut protein isolate may be used for the tonic of buffalo milk. This milk contains approximately seven per cent butter fat or more compared with 3.0 to 3.5 per cent in cow's milk. The value of buffalo milk supplies can, therefore, be nearly doubled by adding dried skim milk and water

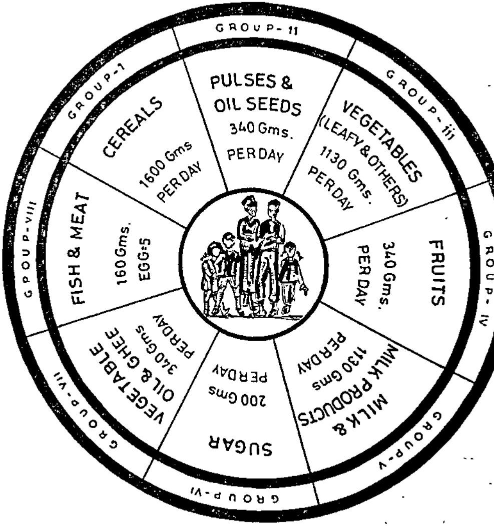
to arrive at the protein and fat composition of cow's milk. Equipment for a process developed by the CFTRI, Mysore has been installed in Bombay by Tata Oil Mills to produce Groundnut protein isolate for the purpose. Milk toned with this product has an excellent flavour and acceptability and the same nutritive value as cow's milk.

4. *Processing of foods :* As a result of advances in food technology processing has added a variety to the foods for people in many countries. For India an added advantage of processing will be to save fruits and vegetables from wastage during the glunt periods and it will also stabilise the prices. Canning and preservation of fruits and vegetables, de-hydration of onion and potatoes, and tomato products are some of the openings in this direction.

Efforts at family level : A family is the most important social group in India. Things planned at family level can take practical shape more quickly and effectively. Table 2 contains the requirements of calories and some essential nutrients for a family of five members. We shall now consider the planning of diet which would provide these essential nutrients in the needed amount and proportions. A balanced diet should contain different types of food in such quantities and proportion as is the need for calories, minerals, vitamins and other nutrients both for daily use and some extra nutrients to withstand short durations of leanness. Taking into account the foods which commonly our countrymen eat, a diet for an average family is suggested in Figure I.

Some adjustments in proportions and quantities of these foodstuffs can be made according to the availability and eating preferences of a particular family. Persons who do not normally consume meat, fish or eggs can obtain a balanced diet by increasing the quantities of milk, pulses and fruits etc. Most of these foodstuffs, can be produced by families on home scale with some effort and interest. The vegetables can be raised by maintaining a small Kitchen Garden. Similarly the requirement of eggs can be met by keeping a few poultry birds. A very useful literature is available on "how to do these things" and any family with real interest should not find any difficulty in getting the things started.

COMPOSITION OF A BALANCED DIET SUITABLE FOR AN AVERAGE FIVE MEMBER FAMILY.



NOTE.- THE QUANTITIES OF VARIOUS FOOD STUFFS HAVE BEEN CALCULATED FROM COMPOSITION OF A BALANCED DIET SUITABLE FOR A NORMAL ADULT MALE.. PUBLISHED IN THE SPECIAL REPORT SERIES NO 42 OF THE INDIAN COUNCIL OF MEDICAL RESEARCH NEW DELHI 1963

TABLE 2

Requirement of calories and some essential nutrients for a family

Member	*Net calories*	*Protein gm.*	*Ca gm.*	*Iron mg.*	*Vit. A I.U.*	*Vit. B mg.*	*Vit. C mg.*
Father	2800	60	1.0	25	3500	1.5	50
Mother	2300	45	1.0	25	3500	1.5	50
Adolescent	2500	100	1.2	20	3500	1.5	40
Child	1800	60	1.2	20	3500	0.5	40
Infant	1500	42	1.2	20	3500	0.5	40
Total per day	10900	307	5.6	110	17500	5.5	220

Role of horticulture in supplementing food : The main food of majority of our people consists of cereals and pulses, and meat, fish and milk form a very insignificant part. Such a diet is perhaps sufficient in calories but mostly poor in other nutrients, especially animal proteins. A diet dominated by cereals is generally poor in minerals. If tubers are used the vitamin and protein contents remain low. The consumption of carotene will be low in all cases except when yellow sweet-potato or yellow maize are used. Therefore, vegetables and fruits have to function as a supplementary source, not only of vitamin C and, sometimes, of minerals, but also as a source of supplementary proteins of special amino-acids, carotene, and other vitamins. Green vegetables prove to be exceptionally good supplementary foods. Moreover, the percentage of their protein calories is very high, being 20 per cent and 50 per cent which is surpassed only by fish. This makes the greens an excellent supplementary food for raising the protein calories. For the provision of vitamin A and C, use of 100 gm. of greens per head per day appears more than enough. Although pulses and beans are also very important for protein supplementation, dark green leafy vegetables, have some special advantages. Young leaves are more easily digested than pulses and their amino-acid composition is often more favourable. Leaves of green vegetables are not only relatively richer in protein, but also in carotene,

vitamins B and C, and minerals Banana, a cheap and easily available fruit throughout India, is an excellent source of histidine, one of the essential amino-acids.

Scope of choice : Cereals are the cheapest source of calories and an important source of proteins in the Indian diet. Pulses are rich in proteins and are known as the "poor man's meat". Table 3 contains the essential amino-acid contents of certain Indian foodstuffs. In general, cereal proteins are deficient in lysine and tryptophan amino acids. The pulses are deficient in methionine and tryptophan. The leafy vegetables are poor in methionine contents. Mutual supplementation among plant protein foods like cereals, pulses and leafy vegetables is, therefore, important.

Another important choice lies in the cost involved. It is generally believed that well-balanced diets are more expensive. And any attempts to improve the diet are likely to be limited by the income of the family. A very important fact to remember in this regard is that a wide choice of cheap foodstuffs is available in the country and a judicious use of these will greatly help in correcting the dietary inadequacies.

Fruits should be included in the balanced diet particularly in children's diet, but generally the question of cost precludes the use of fruits. In such cases a higher intake of green leafy vegetables will provide at lesser cost the nutrients usually obtained from fruits. Tomatoes and mangoes are richer in vitamins and cheaper in cost, and, therefore, can make a useful addition to diets of the underprivileged people. To cite an example of selecting nutritional food at lesser cost let us compare carrot with apple. From the same quantity of edible portion carrot provides three times as much protein, four times as much minerals, three thousand times as much vitamin A, two times as much vitamin B and $1\frac{1}{2}$ times as much vitamin C.

In the end it is interesting to note that a large number of well-to-do people in India and elsewhere who could afford an excellent diet for their families also suffer from serious malnutrition and deficiency diseases. The task before us is how to strive to improve the diet of our people and how to educate the "educated".

TABLE 3

Essential amino-acids in certain foodstuffs

S. No.	Name of food stuff		Lysine	Try-pto phan	Me-thio nine	Argi-nine	Histi-dine	Phenyl ala-nine	Cys-tine	Threo-nine	Leu-cine	Isolev cine	Val-ine	Approx. nitro-gen	Total per-cent
1	Wheat	..	0.14	0.07	0.12	0.33	0.09	0.33	0.14	0:16	0.41	0:22	0.25	0.72	
2	Rice	..	0.23	0.06	0 18	0.72	0.19	0.32	0.09	0.25	0.55	0.32	0.42	1.34	
3	Gram	..	0.43	0.07	0.31	0.52	0.36	0.31	0.08	0.22	0.42	0.30	0.31	4.18	
4	Beans	..	0.43	0.03	0.11	0.53	0.30	0.43	0.08	0.25	0.55	0.36	0.31	4.01	
5	Potato	..	0.42	0.04	0.06	0.33	0.08	0.26	..	0.24	0.34	0.33	0.31	0.26	
6	Spinach	..	0.78	0.01	0.04	..	..	0.10	..	0.16	0.61	0.38	0.31	0.32	
7	Banana, green variety	..	0.36	..	..	0.38	0.52	0.15	0.11	..	..	..	..	0.13	
8.	Fish (shark)	..	0.03	0.05	0.13	0.33	0.11	0.23	0.06	0.34	0.49	0.34	0.27	3.47	
9	Cow's milk	..	0.55	0.08	0.15	0.19	0.12	0.21	..	0.32	0.55	0.22	0.38	0.51	

Compiled from Gopalan, C. and Balasubramanian, S. C. 1963. The nutritive value of Indian Food and the planning of satisfactory diets. 6th Ed. Indian Council of Medical Research, New Delhi.

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Processing of Feeding Stuffs

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Our country has a very large bovine population comprising 175.7 million cattle and 51.1 million buffaloes. Of these, the former constitutes about one-sixth and the latter one half of the world population of these two species. The cattle census figures of 1961 reveal that the quinqueninal increase was 10.7 per cent in cattle and 13.9 per cent in buffaloes. For providing proper nutrition to this colossal livestock population, the resources of the country in respect of cattle feeds, both roughages and concentrates are woefully inadequate. It has been estimated that against the annual requirements of 932 million tons of roughages and 40 million tons of concentrates, the actual availability is hardly 750 million tons of roughages and 13 million tons of concentrates. Consequently the majority of the animals remain semi-starved and give very poor performance. On account of our needs for feeding a rapidly increasing human population, it may not be possible to divert more area for growing fodder crops or pastures. Thus we are left with no choice except to improve the utilization of the present available resources with us.

The straws of cereals and millets, such as wheat, paddy, maize, *bajra* and *jowar* and dry natural grasses (usually cut after they have shed their seeds) are the chief roughages and form the main-stay of our cattle for meeting their energy requirements. A very limited area is put under green fodders and that too, is confined mostly to a few states like, Punjab, Haryana and Maharashtra. The concentrate part of the animal ration is limited to oilseed cakes, byproducts of starch factories using maize as raw material and brans of

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wheat and rice. The question of sparing grains, despite their being very rich in total digestible nutrients, for the animal hardly arises in view of their shortage even for the human population.

The investigations conducted in the Department of Chemistry & Biochemistry have shown that considerable headway can be made in improving the nutritive value of the roughages mostly straws by suitably processing them. This will form the subject of discussion today.

Before one can appreciate the significance of the methods of processing straws, one needs to have an understanding of their main constituents and their characteristics, vis-a-vis the digestive processes in ruminants.

As the grain plants mature, a large part of the more valuale nutrients such as proteins, soluble carbohydrates including starch, lipids and phosphorous compounds are transferred from the leaves and stems and stored in the ripening seed. So the straw which consists of the mature leaves and stems without the seeds has relatively little protein, soluble carbohydrates, fat, vitamin A or phosphorous. It consists essentially of cellulose, hemicelluloses and lignin. The chemical composition of typical straw is given as under :

Wheat straw (dry matter basis)

True cellulose	*Hemicelluloses* *Zylan polyuronides*	*Lignin*	*Protein*	*Lipids*	*Ash*
35.0	32.0	16.0	2.5	0.5	5.5

Of the three main constituents of straw, viz., cellulose, hemicelluloses and lignin, the former two are polymers of mostly hexoses, pentoses and uronic acids and can be hyrdolysed into constituent sugars but lignin which is a condensation product of a variety of aromatic nuclei having a high molecular weight, is one of the most resistant compounds in plants. It is deposited in the interestices of unicellar fibrils of cellulosehemicellulose complex forming the cell wall.

Thus lignin provides a sort of protection to cellulose and hemicelluloses from the action of cellulose and the enzymes capable of hydrolysing the constituents of hemicelluloses.

For the digestion of cellulose and hemicelluloses, the main energy sources in straws, nature has not provided any secretary enzymes in the digestive system of large animls. In ruminants, however, there exists a mechanism by which these ingredients of the straw can be made use of by them. Ruminants (animals that chew the cud) including cattle, buffaloes, sheep and goats have a more complicated stomach than human beings, horses, and others with a simple stomach. A ruminant has a compound stomach having four distinct compartments. Of these, the first and by far the largest in grown-up animals is the rumen, the second is reticulum, the third omasum and the fourth abomasum, the true stomach. Enzymes are secreted only in the abomasum as is the case with mono-stomach animals. Ruminants owe their ability to utilize cellulose and hemicelluloses to microbial fermentation caused by protozoa and bacteria inhabiting the rumen, the end-products being short chain fatty acids consisting largely of acetic acid, propionic acid and butyric acid. These acids are absorbed through the rumen wall and are responsible for meeting about 80 per cent of the energy needs of the animals. The rumen microbes, besides digesting cellulose and hemicellulose, break down most of the feed proteins and other non-proteinous nitrogen compounds such as amides of the feed and urea of the copious salivary secretions into ammonia which is converted into microbial protein. It is this microbial protein having a high biological value which undergoes normal digestion in the true stomach and small intestines and is utilized by the animal.

Methods of processing :

1. *Fortifying poor straws with missing elements :* As already explained, the straws being very deficient in proteins, soluble carbohydrates and phosphorous, are unable to maintain the animals in good health. They have to be supplemented with concentrates, such as oilseed cakes and leguminous grains which are rich sources of protein and phosphorous. Being costly, they raise the cost of the ration. Keeping in view the metabolic processes taking place in the

rumen, one can infer that cheaper substitutes such as urea, mollasses and bone-meal can serve the purpose. The incorporation of urea and molasses has its own limitations. Urea gets hydrolysed into ammonia very rapidly and is absorbed through the rumen wall and entering the portal system reaches the liver to be converted back into urea. In case there is an excessive production of ammonia which is beyond the capacity of the liver to detoxify, it gets into the general circulation and causes toxicity. Similarly, excessive amounts of molasses in the ration have been found to reduce the cellulolytic activity in the rumen. Hence keeping these factors into consideration, methods have been evolved to reduce the chances of toxicity by urea. It has been seen that by spraying the straw with a dilute solution of urea and giving an outer coating by spraying molasses containing bone-meal or some other source of phosphorus, the concentration of ammonia in the rumen liquor is kept at a low level thereby increasing the efficiency of its utilization and decreasing the chances of toxicity.

The limited amounts of urea and molasses save not only the proteins of the conventional feeds, but also increase the digestibility of cellulose of the straw as given in the table :

Digestibility co-efficient of detergent fibre :

1. Wheat *bhusa* (unprocessed)	.. 44
2. Wheat *bhusa* (processed)	.. 55
3. Wheat *bhusa* (supplemented with concentrates)	.. 45

It has been observed that there are some factors in lucerne, the nature of which is yet unknown, which increase the cellulolytic activity in the rumen. Experiments are in hand to determine the beneficial effects of the inclusion of some lucerne meal in the fortification of the straws with urea and phosphorous.

2. *Grinding and pelleting of straws :* While discussing the nature of the main ingredients of straws, it was pointed out that lignin being in considerable amounts reduces the digestibility of cellulose and hemicellulose complex in which it is embedded. This is probably due to less surface of the

cellulose fibrils exposed to the cellulose digesting micro-organisms in the rumen. It has been found that grinding of the poor straws increased the rate of cellulose digestion. Dr. Moore in his review on the effect of grinding and pelleting of feeds has arrived at the following conclusions :

1. Time of prehension and mastication is reduced.
2. Dry matter intake is increased.
3. Salivary secretion is probably decreased.
4. Rumination time is decreased.
5. The rate of fermentation is increased.
6. The concentration of volatile fatty-acids in the rumen fluid is increased.
7. Ratio if aceti/propionic acids is narrowed.
8. *p*H value of the rumen contents is decreased.
9. Rate of digestion is increased.
10. Passage of food particles through the rumen is faster.
11. Reduction in the digestible coefficient of dry matter and crude fibre.
12. No difference in the net energy value of the feed.
13. Grinding is responsible for these effects.
14. Increased acceptability of ground and pelleted feed.
15. The finer the grinding, the greater the effect.
16. Feeding value of poor forages increased more than that of good quality forage.
17. The feeding of long straw or hay along with ground straw is advantageous.

3. *Treating straws with chemicals :*

(a) *Alkali treatment :* Removal of lignin by treating the straw with a dilute solution of alkali thereby increasing its nutritive value has been tried in a number of countries. The digestibility of cellulose in the straw is considerably increased, but the loss of equally important hemicellulose is more than the gain in higher digestibility of cellulose.

(b) *Chlorination :* Lignin can be removed by the chlorination of the straw without affecting its hemicellulose fraction. The residue left over after treating it with chlorine consists mostly of cellulose and hemicellulose complex and is known as holo-cellulose. The '*In vitro*' digestibility studies (a technique in which the conditions obtaining in the rumen

are simulated in the laboratory) of this fraction, i.e., holo-cellulose were made in the laboratory. The results are given below :

'In vitro' digestibility of cellulose

	Period of incubation (Hours)			
	2	24	36	48
Wheat *bhusa* ..	10.5	21.7	37.1	46.6
Holo-cellulose ..	62.5	68.1	75.0	77.5
True cellulose (Hemicellulose removed from holocellulose with dilute alkali) ..	11.5	49.2	68.1	74.0

These results reveal that the presence of hemicellulose appears to help the digestion of cellulose particularly in the initial stages of fermentation. Very little is known about the exact role played by it in this respect. Work is in progress for determination of the functioning of hemicellulose vis-a-vis digestion of cellulose and the practicability of this method of the removal of lignin which seems to be the main stumbling block to the optimum utilization of the energy giving ingredients of the straws by ruminants.

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The Quest and Conquest of Animal Diseases

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The subject of the history of diseases of animals and their conquest by man has always attracted the attention of persons engaged in various disciplines, as disease and suffering have always coexisted with life. Measures to control the various diseases have also been as old as the disease itself, though they differ from time to time and from place to place. The disease in early days was considered to be a wrath of evil spirits and divine vengeance on people due to their wrong doings. This belief led to very strong opposition, torture and humiliation of early workers who departed from tradition and attempted to reveal the true nature of the various disease processes.

Humanity owes a great debt to those undeterred and devoted pioneers who in the teeth of all opposition continued to strive hard in the quest and conquest of animal diseases. The scope of this paper is so vast that it is difficult to touch all the aspects. However, the subject in this paper is restricted to include only the history, epidemiology and control of animal diseases. The diseases referred to here are those which have influenced the animal breeding programme of our country.

It may be interesting to point out that Veterinary

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Medicine took its birth in India. The oldest record about it is available in "Rig and Atharva Veda" about 4500 B.C. where treatments of many common veterinary ailments are mentioned. The world 'Salihotry' still used as a synonyms for Veterinary Surgoeon is derived from 'Salihotra' the ancient authority on horses. The priests, philosophers and lately the scientists practised medicine in different ways. Certain measures adopted even now for controlling some diseases have a background of tradition and precedent. Many such measures have outlived their usefulness and have been replaced by newer discoveries.

Though ancients knew nothing of microbes, still records are avilable where some sages or physicians have laid stress on cleanliness which reduced the incidence of death very significantly.

After Pasteur and Koch, who cleared the mystery of infectious diseases by demonstrating their germ theory of transmission of disease, scientists get aside to find antibacterial agents which would be harmless to body tissues. Ehrlich was the first to discover Salvarsan 606 known as the 'Magic Bullet' which acted on these principles. Later many such compounds, e.g., sulphonamides and antibiotics were added to this list.

With the advent of better chemotherapentic agents, the methods of diagnosis and surgical techniques, rapid strides were made in the progress of Veterinary Medicine. After visualizing the success of medicine in the conquest of disease, Prof. Kettering (cited; Paul De Kriuf) remarked thus "The doctors tell us certain diseases that are incurable. Do you know what an incurable disease is ? It is one that the doctors don't know anything about. The disease has no objection to being cured at all". In short the modern man is fully-equipped with all weapons at his command to fight the diseases which in earlier days were responsible for tremendous losses in men and animals.

The following discussion is devoted to the diseases which are potential enemies of our livestock but against which the steps have been taken to curb the losses and devastation caused by them. Had the incidence of these diseases not been sharply curtailed, it would be unthinkable to find the

healthy and economic animal population of today.

Rinderpest : Rinderpest is the oldest and deadliest of cattle diseases and is regarded as cattle enemy No. 1 since up to the recent past it was responsible for 60 per cent mortality in cattle. The veterinary departments in most of the countries, especially in India, owe their existance to Rinderpest since it was for controlling this menance that the departments were created. I.V.R.I. was also established in 1890 with the sole aim of preparation of vaccine to combat Rinderpest.

Many preventive methods were adopted. Starting from the simple immunization techniques, sophisticated vaccines like Freeze dried Goat Tissue and Virus Vaccine, which is now being used. Eradication of Rinderpest from India is nearly complete except for some sporadic outbreaks which have occurred in certain regions.

Ranikhet disease (New castle disease) : This is an acute febrile disease of fowl and was first recognized in 1926. During the next decade the disease spread throughout the world and was further disseminated in World War II. It causes considerable economic losses by causing heavy mortality among birds, loss of production in growing and laying hens, impaired egg shell and egg albumin quality. Indirect loss is associated with restriction of exports of poultry and their products to unaffected countries. The control programme of Ranikhet Disease rather than treatment of affected birds is being practised. Two types of vaccines, killed or attenuated virus are being used. The disease was eradicated from Australia and South Africa in 1933. England and other European countries have also practically eradicated it.

In India, also, the incidence of outbreaks of Ranikhet Disease has significantly come down with the methods of prevention undertaken. As a result, the poultry raising is becoming more and more profitable.

Foot and mouth disease : This disease of ruminants and pigs is of almost worldwide distribution. The affected animals lose condition, showing a fall in milk yield, abortion, sterility and chronic lameness resulting in great economic

losses. Indirect losses also accrue through loss of foreign exchange on the export of such animals and animal products.

This disease was recognised in Norway as early as 1764. A very serious epidemic broke out in Europe in 1951-52 and resulted in a direct loss of one billion pounds (White and Jordan, 1963). North America is now successful in freeing herself from this menance.

Different methods of immunisation against this disease have been attempted. Many countries including England, France, Belgium and Argentina with their policies on import restrictions, quarantine methods, immunisation techniques and slaughter policies have reduced the incidence significantly. Indian animals fortunately are not so susceptible to it as the imported animals. The preventive steps taken in India are generally limited to mass foot baths to animals in the reported area. The different foot and mouth virus vaccines prepared till date do not afford a sufficiently long immunity against it and no single vaccine can protect the animals against all the forms of this pleomorphic virus. Efforts are, however, being made to improve the immunogenic methods.

Bovine tuberculosis : The disease responsible for tremendous economic losses and severe public health hazard at one time has been greatly brought under check both in India and other countries. Many of the advanced countries with their vast resources have completely eradicated this disease. In India, too, the disease these days does not pose a very serious problem. T. B. control programme on the pattern of Bang's method of T. B. eradication was started in Government Livestock Farm, Hissar. The incidence of bovine tuberculosis which was around 20 per cent in the beginning has been brought down to less than $1\frac{1}{2}$ per cent.

Brucellosis : Brucellosis is an important disease of livestock because of economic losses and more so because it is communicable to human beings. The disease is hereditary and thereby further aggravates the situation and affects adversely the breeding policy. The exact incidence of disease in this country is not available but it is reported that after adopting the policy of testing the animals for brucellosis and segregating the affected animals, the incidence was brought down from 16.3 per cent in 1952-53 to 0.83 per

cent in 1957-58 in buffaloes at the Government Livestock Farm, Hissar.

Rabies : Since very early days it has been recognised as a disease communicable to man and its treatment was influenced by ancient beliefs. The treatment and prevention of this disease has now been rationalized and many countries of the world enjoy freedom from it. In India, where dog destruction arouses public resentment, the disease is still unfortunately prevalent. England eradicated it in the early years of 20th century and it has been reported that from 1922 to 1957 only 23 cases of rabies occurred in U.K. and all were in quarantine.

Cancer : Another field where the scientists are working is cancer chemotherapy. Unlike microbial diseases, which are caused by extraneous pathogens, cancer is caused by the malignant cells which are the flesh of our flesh and are similar to the normal cells. The search for cancer remedies is, however, being made on the same principles as of infectious diseases. The concept of chemical competition explains the mechanism of action of the sulphonamides. This suggests that a slight alteration in the structure of essential metabolites of microbials could act as an imposter and deceive the organisms. Sidney Farser extended this concept to the advancement into cancer chemotherapy and the same is reported to be progressing. He employed folic acid analogues e.g. Aminopterin and Amethopterin and other analogues of Purine and Pyrimidine bases for this purpose.

To sum it up it may be stated that it is mainly the infectious diseases which have been major hazards of public and veterinary health. People had recognised this fact from times immemorial and various control measures had been adopted. With the passage of time and the progress made in this direction, it has been recognized that the following control measures are best suited to combat most of the infectious diseases.

1. The preventing or minimizing the contact between host and infective agent.

This is best accomplished by :
(a) Restricting the import of animals from sources of

infection.

(b) Quarantine of the imported animals to check the infection if in the incubation stage.

(c) Slaughtering or disposing off the infected or sick animals.

(d) Controlling the biological and mechanical carriers, vectors and intermediate hosts.

(e) Disinfecting the sources of infection i.e. contaminated material.

2. Increasing the resistance of the host by means of vaccines and antisers.

3. Treating the affected host.

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Advances in Clinical Medicine (Veterinary)

S. C. Datt
M.S.

Proper diagnosis of animal diseases is evidently the basis of treatment, prophylaxis and control. The method of proper diagnosis and the different techniques adopted for this purpose elevate this technique to a scientific and rational procedure. Correct recognition of disease is the only reliable basis for any subsequent measures. The place of clinical medicine in the sphere of animal industry is unique. There are a great variety of diseases, especially, the infectious types, which if undetected or wrongly diagnosed, can cause a great economic loss.

In this short discussion it is not possible to touch each facet of the problem and, therefore, only a few latest developments in this field are discussed. The laboratory techniques of blood, faecal and urine examinations have altogether been ignored. These laboratory techniques are well-established and form the normal diagnostic schedule in any good veterinary clinic. Rather than repeating established techniques, new methods which have been added during the last decade are discussed below :

Radiology : Only in recent years has radiology been considered to play a vital role in veterinary medicine. It offers an insight to the internal hidden structures. For proper visualization it is recommended to have at least two views. Single view is only one dimensional and, therefore, can be grossly misleading. After obtaining a developed X-ray film of the part, it is always convenient to classify the

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condition to one of the following :

1. Developmental
2. Metabolic
3. Traumatic
4. Infectious
5. Neoplastic
6. Degenerative

The basic radiologic signs of pathology are in terms of the following tissue changes :

1. Size
2. Architecture
3. Contour
4. Density
5. Position
6. Function

There are numerous internal conditions which can conventiently and conclusively be diagnosed radiologically. A few examples are :

1. Pulmonary and mediastinal tumours
2. Pleurisy
3. Pneumonia and bronchopneumonia
4. Diaphragmatic hernia
5. Lesions of the gastric and intestinal mucosa
6. Cystic and prostatic calculi

Various techniques employed in radiology are :

1. *Barium contrast studies of the gastro-intenstinal tract :* The technique is particularly useful in studying the oesophagus. The stomach my show tumours, ulcers and foreign bodies. The barium enema is useful for studying large bowel. Gelatine capsules containing barium sulphate have been used in the diagnosis of oesophageal obstruction in the dog.
2. *Cystography :* This is performed by injecting air or a contrast medium into the bladder. The technique is used to study different conditions of bladder including neoplasia, cystitis, cystic calculi, ruptures bladder and displacement of the bladder

by growths in the viscera.

3. *Intravenous pyelography :* This technique is used for studying the excretory pattern of kidneys. It is useful in detecting neoplasia, cystic kidneys or malformations.
4. *Pneumoperitoneum :* This is a simple technique in which the affected organ is viewed against the background of low density gas. Clear and detailed examination of the kidneys, liver, spleen and other organs is possible with this method. The internal genitalia of the females is also clearly visualized.
5. *Fluoroscopy :* Because of the radiation hazard, this method should normaly be avoided. This is only useful when the character of motion is visualized viz., :
   (i) Pulmonary emphysema—the diaphragm will pulsate but will not show normal inspiratory and expiratory movements.
   (ii) Pericardial effusion—the heart shadow will appear to vibrate and will not show the usual pulsating beats.
6. *Bronchography :* Radio-opaque material is injected into the left or right main bronchus. The posture of the animal is adjusted during the injection to aid the spread of the medium throughout the bronchial tree. All radiographs are taken in full inspiration, using the shortest possible exposure time.
7. *Hysteriosalpingography :* This is found to be suitable technique when the pathologic changes of the canine genital system are suspected. Selection of a suitable dye is rather important.

Electrocardiograph : Electrocardiography is an instrument which keeps a permanent visual record of the very small electric currents generated in the heart during various phases of muscular activity. The letters P, Q, R, S, T, are used to describe the components of the record obtained from the complete cardiac cycle.

There are various methods of application of electrodes in large animals. The commonest method is the application on the left fore leg, right fore leg and left hind carpus and above the tarsus. Electrical contact is ensured by the application of a suitable paste on the skin·

Traumatic pericarditis shows increase in the heart rate but the regularity of beats is maintained. In the majority of cases, the electrical axis of QRS varies with a wide range.

Myocardial fibrosis in bovines shows evidence of ectopic beats of ventricular origin. The ventricular extrasystoles, whether occurring singly or in groups, are followed by a full compensatory pause. Gardiac arrhythmia may be a predominant feature.

Electroencephalograms (*EEG*) *:* An EEG is necessary for evaluation of neurologic status of a dog suspected of having cerebral disorders.

Technique :

1. The skin of the scalp is defatted by rubbing acetone.
2. To prevent pain a long acting local anaecthetic (e.g. xylocaine) is injected into the subcutaneous tissue at the point of application of electrodes.
3. Electrode paste is applied and rubbed into the area where the electrodes pare attached.
4. Suitable sites of electrode placement are :
   2 over the frontoptarietal area
   2 over the occipital area
   1 over the vertex crani
5. With an eight channel EEG recording system all of these can be recorded simultaneously.

Significance of EEG :

1. High frequency series of spikes are indicative of focal lesions in the brain.
2. In dog distemper 30 per cent of the cases result in viral encephalitis. This is easily distinguishable. The pattern consists of continuous low voltage or slow waves combined with runs of low voltage activity.
3. In severe traumatic injury to the cranium resulting in subdural haematoma, the EEG recording has a hupersynchronous pattern.
4. In deep surgical anaesthesia, there is spike and suppression.

Thermometry : This is one of the commonest clinical procedures yet it is not very well understood. There is such a wide variation of temperature that it can even safely be said that there is no normal temperature for any species. There is even a wide variation within the body itself. The skin around the feet may have temperatures 10° to 20°F below the rectal temperature. Environmental temperature and exercise may increase the body temperature by two or more degrees.

There is a temperature variation during a 24 hours period. The temperature is highest from 8 to 11 p.m. and lowest from 2 to 6 a.m. This in general, is true when an animal is suffering from a febrile disease.

There is no evidence to support the old theory that pyrexia stimulates phagocytosis, antibody formation or any other defence mechanism. On the other hand it has certain detrimental features viz., increasing metabolic processes, nitrogen wastage and increase in the work of the heart.

In general, the pulse rate increases ten beats per minute for each degree of fever. The respiratory rate will increase two or more cycles per minute for each degree of temperature increase. This, of course, does not apply to respiratory infections and meningitis. The basal metabolic rate will increase about 7 per cent per degree of temperature increase. In general, the pathologic causes of increased temperature are :

1. Infections.
2. Mechanical injury to any tissue.
3. Neoplastic diseases.
4. Haemopoietic disorders and infections.
5. Acute metabolic disorders.
6. Drug reactions.

Priorities in Animal Science Research

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Research is the foundation of all true and permanent progress of the nation. But the results of research hidden in 'ivory towers' of the laboratory are of little value until they are applied to basic problems. Scientific research can be tremendously complicated and expensive and also relatively simple and inexpensive. There is still room for the string, wood and sealing wax approach as well as that which requires more complicated devices. The true beauty of scientific research is found in its simplicity and orderliness.

It needs no emphasis that the foremost problem today in under-developed countries, including India, is food where the majority of human and animal population is under-nourished. The state of human nutrition depends not only upon the vegetative produce but also on the supply of those foods which directly originate from animals, viz. milk, eggs, meat, etc. Besides, all our agricultural production depends on animal labour. Agriculture in the true sense means crop science and animal science and the two are inseparable from each other. The livestock in less developed countries not only provides food of high quality protein, but also raw materials such as wool, hides and skins, drought power for agricultural operations and valuable organic manure. It is apparent that the final solution of the food problem in India will depend upon the success achieved in producing more products from animal origin.

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India has the lowest per capita consumption of livestock products of milk, meat, eggs and fish, etc. as shown in Table 1 :

TABLE 1

Per capita consumption of livestock products

Name of country	*Milk (grams)*	*Meat per head*	*Eggs per day*	*Fish*	*Protein*	
					Animal	*Total*
North America ..	850	248	55	26	66	93
Oceania ..	574	312	31	22	62	94
River plate countries	460	318	22	10	63	101
Europe ..	494	111	23	38	36	88
All above ..	573	152	30	34	44	90
Latin America ..	204	67	9	20	19	61
Far East ..	51	24	3	27	8	56
Near East ..	214	35	5	12	14	76
Africa ..	96	40	4	16	11	61
All above ..	79	30	4	24	9	58

Source : F.A.O. Bull. The state of food & agriculture, 1962 : 129-160.

As compared to the present availability of about 19 million pounds of milk and milk products, the demand for the same for 1970-71 is estimated to be about 35 million pounds. The annual egg production in the country is about 5,600 million against the requirement of about 100,000 million eggs. Calculated on the basis of one egg per day per head for 50 per cent of the total population, based on nutrition standards.

Our human population, on the average, has been increasing at the rate of 2 per cent per year which makes the problem of milk and egg supply all the more serious. Unless we intensify our efforts there is likely to be an acute shortage of animal products in the years to come.

Productivity of our cattle, sheep, poultry, etc., is poor and thus there is a tremendous gap between the present availability and our needs; inspite of the fact that India possesses the largest livestock population. We have reached a stage of over-stocking with respect to cattle. Table II gives the annual milk production of various countries. India produces 220 kg. of milk per cow on an average as compared to Netherland 4,280 kg. and U.S.A. 4,250 kg. per year.

TABLE 2

Average annual milk production of cows

Name of the country	*Average milk yield per annum per cow (in kg.)*
Netherland	4,280
U.S.A.	4,250
Denmark	3,710
Germany (FR)	3,430
U.K.	2,990
New Zealand	2,750
France	2,360
Australia	2,130
U.S.S.R.	1,740
U.A.R.	680
Pakistan	420
India	220

Increased productivity-prime goal : We need to divert our research efforts to the call of the nation. We must undertake research projects which are of immediate need to the farmer. Our ultimate aim is to increase the production of milk, eggs, meat, etc. How do we achieve this ? An animal will produce the maximum if it has a superior genetic make-up, is fed adequately and is clinically healthy and receives optimum management conditions.

I. Animal breeding : While very little genetic deterioration has taken place in our livestock, we have undoubtedly suffered from lack of genetic improvement. In a given

population, genetic improvement is brought about by the combined process of selection and mating systems. Selection is vital in increasing the frequency of the desirable genes for production traits in the population. This is affected by culling the poor producers from the herd, thereby giving opportunity for good producing animals to spread their genes. Culled animals should be slaughtered or sterilized.

(i) *Selective breeding within a population :* This is the usual form of breeding practice. The animals to be retained are selected on the basis of their own performances or the performances of their parents, siblings or progeny. The selection for traits expressed in both sexes, such as wool and meat production is easier than for those which are expressed in one sex such as milk and egg production. For the latter traits, the selection for the males was hitherto based on the performance of their parents and external appearance. This is not a very reliable measure as compared to the one based on the performances of their progeny. Moreover, a sire is believed to be half the herd and a faulty selection can cause irreparable damage. Thus it is necessary to introduce progeny testing and use only proven sires.

McBride (1965) while dealing with the 'Selection' suggested four practical methods for improving the existing stock :

1. Foundation stock should comprise a wide sample genetic material of high merit.
2. The population size during selection should be as large as possible. The flock need not necessarily be kept closed to outside stock.
3. A similar animal improvement programme should be developed in as many centres as possible to ensure that there are numerous sources of improved stock for out-crossing.
4. Careful consideration should be given to the environmental condition under which animals are measured for selection.

(ii) *Cross-breeding :* The improvement through selection is very slow, about 3 per cent per generation, and in some of the species where generation interval is quite long, it is not very significant. Therefore, superior genes have to be imported in the population through grading or cross-breeding.

Cross-breeding programmes of indigenous breeds like Sahiwal and Tharparkar with Jerseys, Holstein-Freisian and Brown Swiss are likely to yield quick results. Evolving a new breed by crossing the indigenous with Brown Swiss, Jerseys and Holstein would be a sound path of increasing milk production. The success of this programme depends upon the artificial insemination techniques and semen preservation. Sufficient research has been done on these lines and it is now possible to freeze the semen for years together and obtain good fertility.

A spectacular achievement in this way has been achieved in poultry by replacing the indigenous stock with superior foreign stock. Improvement of '*desi*' bird has not produced significant results. The availability of hybrid stock from commercial American breeding companies like Arbor acres, Hy-line, etc., has eased the situation to a great extent. However, I.C.A.R. efforts to improve the existing imported stock and to form inbred lines are steps in the right direction. Jaap in 1967, pointed out that no pure stock of White Leghorn chicks was available in U.S.A.; the hybrid stock commercially available in India may be bred and improved. If this is possible there is vast scope of improvement of poultry stock.

II. Animal Nutrition : Man is not alone in suffering the vicious circle of poverty where low food intake leads to reduced body-weight and low levels of activity. The matter leads to decreased productivity and thence still greater poverty.

Animal population pressure and insufficient animal feeds : According to the available figures of 1958, there were 28 cattle per sq. mile in U.S.A., 59 in New Zealand as against 123 in India; similarly, the number of cattle per 100 acres of sown area is 67 in India as against 38 in Holland, 25 in Egypt, 15 in China and 6 in Japan. Obviously our land cannot possibly meet the requirements of food for such a large human as well as cattle population. It has been roughly estimated that from the total requirements of balanced nutrition for our livestock, there is a shortage of 26 million pounds in straws, about 300 million pounds in green fodder, and 25 million pounds in concentrates. This constitutes a deficiency of about 60 per cent of proteins and

about 47 per cent of energy producing substances required in livestock feeding. It is, therefore, not surprising that our animals in general, are stunted in growth and have low productive capacity and fertility. The number of livestock must correlate with carrying capacity of land areas.

The undesired animals may be culled and preferably slaughtered. Our requirements of bullock for draft purposes will easily be met even after culling or slaughtering. In a study by F.A.O., it was reported that in India seven cows produce one bullock which is indicative of low productivity of our animals.

(i) *Adjustment between soil, plant, cattle and man :* Land use planning implies an effort to ensure that each piece of land is put to its best use. Out of 400 million acres of land available 16 per cent has been earmarked for animal feeds and fodder crops. One hundred million acres of land has an assured water supply which can be used for introducing extra short term leguminous fodder crops in between the regular crops, which will help to produce extra fodder for our animals. Similarly, there are about 50 million acres of fallow land, in half the area suitable fodder crops may be sown during the rainy season without reducing the fertility of the land in the least. Team work between agronomists and animal husbandry men is essential to collect adequate data on methods and possibilities of *land use planning*.

(ii) *Values of Indian feeding stuffs :* The composition of a feed varies with the climatic conditions, kind of soil and the amount of fertilizers used. The foreign data cannot be successfully used in India. Very little work has been done in the amino-acid contents and metabolizable energy of Indian feedstuffs which needs to be studied further.

(iii) *Subsidiary feeds :* An attempt has been made to explore the unused sources of feed. Those that are highly rich in protein and can be used to replace grain in concentrate mixture include mango seed kernel, Jaman seed, panewar seed, tamarind seed, babul pods, entrails and fish. Similarly, coarse grasses such as kans and Mung and certain plants such as Kanitiara, sugarcane tops and panewar straw have been studied as sources of animal nutrition. The value of as many as 42 edible tree leaves has been investigated and

16 species of fodder trees have been recommended for cattle fodder. Unfortunately, none of the above unconventional feeds are commercially available to the dairy farmers, even though some of these were explored as long as two decades ago. Besides intensifying our research efforts on unconventional lines, we must see that concrete steps are taken to make available these products, without which all the efforts are useless.

Since concentrates compete with human food, it is desirable to curtail as much concentrate from the ration of growing heifers and milch cows as possible and replace it by high roughage in the ration. This will help save the concentrate and cut down the cost of feeding.

(iv) *Conservation of feed :* During the monsoons, there is an abundance of immature grass of good nutritive value. Silage making is more suitable for Indian conditions; although it has been recommended by the experts for a long time, it is being carried out only on limited basis. Efforts may be made to make a palatable silage and make it available on a commercial basis.

(v) *Non-protein nitrogen compounds as protein supplement and utilization of by-products :* Urea has been used to the extent of 20-25 per cent to substitute protein in the ration and efforts are being made to replace entire quantity of required protein level with urea in cattle.

Unlike cattle, poultry is unable to consume roughage. Great success has been achieved in using agro-industrial by-products. Rice polish, mollases, antibiotic factory wastes, etc., have successfully replaced the poultry cereal ration. Blood meal, meat meal, bone meal, etc. are also consumed by poultry with good results. Continued efforts need to be made to explore more and more unconventional feed for poultry. To cut down the feed consumption, effort may be made to use berseem or other grasses in the poultry feed. Chickens tend to waste a good quantity of feed. Efforts may be made to standardize feeders, which may decrease this feed wastage. There are indications that cattle manure can be used for poultry feed and in turn poultry manure for cattle. The possibility of this cycle needs to be explored further.

III. Physiological studies : An animal of good breed provided with well balanced feed will not perform well if kept under adverse conditions. The physiological requirements of the body need to be met for better performance. The cross-bred animals and imported breeds need a constant study on their adaptation to our climate.

Day to day changes in weather which include temperature, light, moisture, air movement and radiation from space and the long range weather pattern which characterizes a climate have a profound effect on plant, animals and man. The climate and environment influence nearly every economic aspect of plant and animals—crop yield, animal growth, reproduction, milk production, egg production, and the efficiency of conversion of feed stuff to a more salable product.

During the 19th and early part of 20th century, man practised the philosophy that animals should be adopted to whatever climate existed in the particular place. As a result, there are literally hundreds of breeds of livestock scattered all over India and unfortunately many of them are not productive.

It is now apparent that there is an optimum climatic environment for everybody function. There is a very good possibility, that advances in technology will make it possible to alter or control the large segment of the environment and to more effectively meet the requirement for maximum animal productivity and efficiency.

India is situated between 10° and 35° North. The climate varies from moderate in the South to extreme in the North. The environmental temperatures varies from 32°F to as high as 120°F in the North and 80-100°F in the South. The intensity and duration of light is considerably higher in summer. All these factors, particularly the latter one, is responsible for the reproductive efficiency of animals. We must divert our energies to provide suitable environment to our animals. We have to acclimatize our animals to our environment but not to the disadvantage of production. The effect of light on pituatary gland has been well established in poultry and sheep. There is indication that buffaloes also respond to light as shown by their sexual behaviour. We have established that if proper environment is given to

buffaloes, their breeding season can be extended to the summer season also. Unlike other countries, the breeding season of sheep is not confined to fall and spring season, sheep come into heat throughout the year in this country, provided that a proper environment is given.

It is thus apparent that good breeding and feeding will be of no avail if the physiological needs of the animals are not known.

Thus climatological research is just one branch of the science of animal production. It can serve, however, to bring together the findings of the nutritionist, the pathologist, the parasitologist, and the meteorologist, and assemble them into practical recommendations which will make it possible for the animals to be more effective and of higher quality.

IV. Disease control : The spaying, "The weaker the livestock, the scantier the production, the feebler the nation" is of vital significance to our country where agriculture plays a predominently important role in the national economy. We have to take serious note of the formidable danger of the ravages of animal diseases, which could undo in a short time, all that might be achieved over years of effort in producing quality animals. The other aspect of danger is that survivors from infectious and parasitic diseases, several of which are known to take a heavy toll of animal life and thus may render the animals permanently unproductive. Anothr important aspect is the direct danger to human health from diseases which are communicable from animals to man and vice versa. The eradication of tubercolosis for example in our human population is impossible unless it is simultaneously eradicated in the animal population too.

Our problems are, however, of such magnitude and complexity in different parts of this vast country that there is an increasing demand of our having research centres in different regions. Today we have efficacious vaccines against several of the important animal diseases such as Rinderpest, Ranikhet Diseases, Black quarter, enterotozaemia, etc. More extensive work, however, needs to be done for the effective solution of problems such as foot and mouth disease, brucellosis, salmonellosis, and a systematic study is also

called for newly discovered diseases such as horse sickness, swine fever, mucosal disease, etc.

V. Marketing and technology : Marketing is one of the naked problems of present day Inda. This is particularly true for eggs and meat, where unlike milk, this cannot be converted into products with a long shelf life. Eggs and meat are perishable products. If not consumed within reasonable time, they are likely to be spoiled. The price of eggs and meat are very high during the winter season and considerably lower during summer.

Considerable research is needed for canning meat and drying eggs in this country. Increasing the keeping quality of eggs and meat till they are sold in the market is another aspect which needs our immediate action.

Summary : Our research efforts should be diverted towards the immediate problems of the farmer. Our ultimate aim of research in animal sciences is to increase production, which can be achieved by systematic breeding policies, by providing balanced feed, and by improved management practices. Priorities in research must be given to :

1. Selective breeding within a population based on progeny testing.
2. Cross breeding of Hariana, Sahiwal and Red Sindhi breeds with Jerseys, Holstein—Freisian and Brown Swiss.
3. Use of uncoventional feed stuffs may be further explored.
4. Grasses may be properly preserved for use during the lean days of the year.
5. Studies on climatology should go hand in hand with the breeding and feeding research projects. Research must be done to find out the optimum environmental conditions for each species and the influence of the duration and intensity of light on the sexual behaviour and reproduction of animals.
6. Canning of meat and drying the eggs may be studied.

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Mechanization of Agriculture in India

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Energy is a basic input like water and seed for agricultural production. A tremendous amount of human energy has been put through ages into the production of food and fibre. With the progressive harvesting of power sources other than human, the size of energy input for agricultural production has continuously increased. This permitted the development and use of better tools and machines and the human effort has become increasingly more productive. This process has been phenomenal during the last 50 years in industrially advanced countries where sufficient power became available on the farms. Thus machines with most developed and sophisticated mechanisms came into use for agricultural production. This has played a great role in changeover of agriculture from a mere self-supporting industry to its incorporation in an economy with division of labour characterised by engineering and commercial cost calculations. Within the framework of this development, machines have come to play a role, not only of an aid to agriculture, but also of a driving force of progress.

The present level of energy input in India is 0.2 HP/hect. Recent studies by the President's Science Advisory Committee (U.S.A.) on the world food problem indicate that because of the direct relationship between the energy input and yields per hectare, the average energy input level for agricultural production in India will have to be raised to 0.5 HP/hect. by 1985 to meet the food needs of the country in that year. This does not include the power needs for irrigation which will be substantial in a state like Punjab. Due to the continued limitation in the foreseeable future on the total cultivated

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area in the country and the size of holdings, the additional power is most likely to be utilized for intensifying agricultural production, i.e. producing more per unit area. This trend has already been indicated in the recent years. The process of mechanization may not for a long time create any serious problem of rural unemployment. On the other hand it will create a substantial potential for employment in the industry connected with the manufacture, distribution and maintenance of the additional power units and machinery.

History of machine in agriculture : Some of the oldest machines developed by man were meant for assisting agricultural production. The bullock/horse cart and many water lifting devices were outstanding examples of these. But it was from 1850 onwards only that the machines started occupying a significant position in agricultural production (Cooper, *et al.*, 1947). This was very closely connected with the rapid and effective industrial development in countries of Europe and in U.S.A. A strong demand for labour in other industries resulted in the progressive withdrawing of workers from the land, forcing wages up and this proved to be the major incentive for bringing in more machines for agricultural production. Here again some of the first machines to be developed were for operations like thrashing where the labour requirement was maximum. This is interesting since some of these threshers and binders developed nearly 100 years back were fairly complicated and sophisticated machines compared to those machines which were developed much later for operations in which labour requirement was not critical. Initially, in all industrially developing countries, the start was made with animal drawn machines and by 1910, the agriculture of these countries was saturated by such machines (Richey, *et al.*, 1961). Around that period another revolution was brought in by the introduction of a large and better source of power, i.e., tractors with internal combusion engines. This revived the effort to develop larger and better machines for agricultural production. This process which still goes on is a dynamic one with no ultimate goal in sight. In addition to the economic situation, outstanding advances in the biological sciences of agriculture continue to change the functional requirements and the concepts of use of machines in agriculture.

How do the machines serve ? Machines have served the

man in his desire to produce food and fibre in various ways.

1. *Increased labour output :* It is estimated that with suitable bullock-drawn machines, the output of agricultural labour can be nearly doubled. With the availability of better sources of power like tractors, stationary engines and electric motors and suitable machinery, this output can be raised from 8 to 10 times (Smith, 1965). An example is available in the change in output per man hour in United States from 1910, when the use of animal drawn machines was at its peak, to 1960. It increased to nearly 400 per cent during that period (Jones, 1963).

The increase in productivity of labour resulted in reduced labour requirements on the farm. This has been an important and desirable feature during the period of industrialization in the western countries, although it may not be looked upon with the same favour in our country in the present situation. To sight an example the man hour requirement to grow one acre of wheat in United States has come down from 60 in 1830 to 3 at present. Similarly, the man hours required to grow one acre of corn have been reduced from 33.6 in 1855 (U.S.A. average) to 3.88 in 1949 in Iowa State (Gittins, 1950).

Another effect of increased output per man hour is reflected in availability of more time for growing a particular crop in situations where land is more limited, labour shortage is not acute and high yields are aimed at. This is what is most likely to happen with progressive use of machinery in agriculture in our country for sometime to come. A mid-way example is available from the recent history of agriculture in West Germany, where due to the use of better and larger machines, the labour units per hectare of land was reduced from 27.9 to 19.7 during the years 1950-51 to 1958-59. During the same period the agricultural production rose by approximately 35 per cent (Smith, 1965).

2. *Timeliness of operations :* The machine and suitable source of power equip the farmer with additional capacity for doing a job at a faster rate. This could be more critical for certain operations where a time limit is normally imposed, like sowing and harvesting. When considered with reference, to the recent development of Indian agriculture, particularly

in states like Punjab, where most of the irrigated area is under doubled cropping and efforts are being made to grow even three crops in a year, this additional capacity of work to perform agricultural operations in time is a very important factor.

3. *Greater scope of operations :* There are a number of farm operations like land grading, considered to be extremely important towards creating optimum conditions for crop production, which were not at all feasible with manual or even bullock drawn equipment. Use of better sources of power and machines has widened the scope for the farmer to manipulate the soil, the operations and even the working conditions in order to achieve its target of high agricultural production.

4. *Better quality of work :* Most of the machines designed in West European countries have improved the quality of work as an important objective. It has been so as the size of holdings in these countries was not large and the machines were utilised for producing more from the same area rather than covering more areas. A similar situation exists in our country. The use of machines like seed drills, with no additional input, would ensure improvement in the quality of sowing and increase in yields.

In addition to the above, machines have served the farmer in many other ways in which their role is not very readily appreciated. Use of machines makes the job easier and often more interesting for the farmer. He can work longer hours without feeling tired as he would after walking behind a *desi* plough for some hours. The capability to do the work faster and better gives one more satisfaction. Use of one machine often makes the farmer think more rationally towards organising his farm. For example, the farmer using a thresher may come to the decision that he needs a better harvesting machine and better transport facilities to make full use of the additional threshing capacity at his disposal. This leads to general progress, one step leading to the other.

Present status of machines used in agriculture and future trend :

1. *Tractors :* Although a tractor does not directly perform a farm job, it is in the wider sense the most importnat

machine in agriculture. The amount and type of power available for agricultural production has and will in future determine the development and utilisation of machines in agriculture.

The most common type of tractor used in agricultural production is the all-purpose type machine. Crawler tractors continue to be used for heavy operations on large farming units. The tool carrier type machine has not been able to gain any advantageous position compared to the all purpose tractor. Pneumatic tyres and hydraulic lift tremendously influenced the design and have long been accepted as the standard features and so have the mid and front mounting of harvesting and intercultural machines. The agricultural wheel type tractors are manufactured in sizes from a few H.P. to nearly 100 H.P. There is a tendency throughout the world to increase the H.P. of the tractor. It has been reported for instance that during the last few years the average size of a tractor in U.S.A. increased by 2 H.P. per year (Csorba, 1960). Sometime back 50 H.P. was supposed to be the higher limit for the all purpose wheel type tractors. Now they have been raised to 100 H.P. (Smith, 1962). There is a definite demand in the world market today for certain improvements in tractors, the important ones being : less noisy engines, comfortable seats, protection against weather, ease of operations, light steering, better speed controls, better and quicker implements for hitching, and low maintenance costs. There is some demand for development of a self-steering tractor (Buckingham, 1962). Something has already been done in that line. Design of tractors which would move on an air cushion have also been undertaken (March, 1962). This would solve the problem of traction in marshy and water-logged soils. There is a general appreciation for the need to develop implements and machines which can work at higher speeds (Smith, 1962). This had posed new problem for the tractor designers in terms of chassis suspension. Higher working speeds would make it feasible to utilise large engines on wheel type tractors, maintain low tractor weight. H.P. ratio and solve the traction problem.

There is a general tendency to develop tractor engines with standard components and specifications like bore and stroke and to restrict the engine types to as few as possible (Segler, 1963). Single cylinder engines are hardly used any

more on tractors and the minimum number of cylinders is usually two.

The development of steplers and hydraulic transmission has not reached a stage where it could be widely introduced in tractor manufacture (Scifert, 1962). There is an increase in number of four wheel drive tractors. In some cases the maximum tractor speed has been designed as high as 65 km. per hour (Segler, 1963).

In India five makes of wheel-type tractors are being manufactured, namely Hindustan—50 and 35, Massey Ferguson-1035, International B-275, Escorts 27 W, 37 and 47 and Eicher-115/8. These are all–purpose machines with H.P. ranging from 15 to 50. Accessories like the front loader and features like arrangements for mid and front mounting of equipment are not yet common. Against a sanctioned capacity of 20500, 7520 tractors were manufactured in the country during 1966. Here is a definite demand for a 12-15 H.P. low cost tractor in the country.

2. *Soil working machines :* The soil working parts of the machinery of the future will be designed to work at much higher speeds than at present. This is likely to introduce many problems including a provision of devices to protect the soil working parts from serious damage in case they strike obstructions (Segler, 9163).

3. *Sowing and planting machines :* The placing of fertilizer in measured quantities along with sowing or planting is becoming more and more acceptable a practice. Efforts are being made to develop seed drills in which the spacing of seeds in the row can be fairly accurately controlled. The tendency is to develop sowing and planting machines which can be operated at higher speeds than common at present. Band application of fluid fertilizer is gaining more popularity.

4. *Harvesting machines :* Harvesting involves a chain of operations and in the western countries, recently efforts have been made to think in terms of mechanising all these operations so that each one of these fits in properly with the rest. Harvesting speed has been increased and this has modified the requirements of cutting mechanisms. Instead of the conventional stationary ledger plates and moving knife section,

cutter bars with ledger plates and knife section moving in the opposite direction have been developed (Phillepp, 1962). For fodder harvesting, the tendency is to go in for rotary cutting machanisms, and also to incorporate the devices which harvest and chop the fodder at the same time. The collecting, transporting and unloading operations for fodders have been mechanised to fit in with the new harvesting machines.

The harvesting and the combining of the cereal crops is becoming more and more popular in the world and self-propelled combines continue to replace the pulled ones. From the design point of view, there is a definite scope for bringing in more improvements in the combines. These could be made more multipurpose. The operator's seat or cabin could be more comfortable. In the East European countries, trials are being made with sandicator type of thresher mechanism in the combine while in the western countries, efforts are being made to develop components which could do more than one job of harvesting, threshing and separation or cleaning of straw from the grain (Segler, 1963). The use of the field harvesting machine has brought in the necessity of harvesting at higher moisture levels.

The harvesting of crops like potatoes has not yet been fully mechanised as even in the best machines, manual assistance is required to separate out foreign material like stone and soil lumps.

The scope of machines in agriculture will continue to change according to the progress in economic field and in biological sciences. There would always be some instances where the machine would be designed first and then efforts made to find a work for it. But such problems will not be acute in the future as they have been in the past. Machines have a definite role to play in Indian agriculture. In the western countries, particularly in U.S.A., the main objective of mechanisation was to reduce the labour requirement in agriculture leading to even sacrifice of other advantages in terms of conversion systems. Under our situation, conversion systems must take priority over anything else to obtain maximum yields. This makes the problem of designing and developing suitable tractor for Indian agriculture in many ways more challenging than it was in the West.

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Post-Harvest Care of Foodgrains

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Amongst the many human foods produced through agricultural practices, cereals, millets and pulses are relatively stable under the normal post-harvest conditions of handling. Possibly, on this account, these constitute a major portion of the food in India, which is held in storage. High rate of growth of human population in the country during the last two decades meant a heavy strain on the available supplies of foodgrains. This necessitated imports from outside and the storage of grain assumed appreciable significance. Studies on grain technology and the factors contributing towards minimising qualitative and quantitative losses, have made encouraging progress during this period.

Coyne (1945) reviewing the storage facilities available for commercial stocks of foodgrains considered the warehouses not suitable for holding grain over long periods of time. Pest infestation was a serious menance and practicable effective measures of pest control were lacking. The knowledge relating to deterioration also appeared to be confined mainly to the quantitative losses caused by pests which were estimated at 5 per cent. A survey carried out by the Food and Agriculture Organisation of the United Nations, around this time places the estimate for storage loss in India at about 10 per cent although the Federation of Foodgrain Dealers in the country felt that loss in the handling of foodgrains in the private sector was normally within the range 3 to 5 per cent (Anonymous 1967). The Government of India assumed the role of the largest single agency handling annually 5-10 million tonnes of grain. They took a number of steps and the annual average losses during the period from 1960

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to 1967 decreased steadily. (Table 1).

TABLE 1

Annual average losses suffered in foodgrains stored by Government of India

Year		*Loss* (%)	*Year*		(*Loss* (%)
1961-62	..	0.161	1965-66	..	0.130
1962-63	..	0.240	1966-67	..	0.140
1963-64	..	0.207	1967-68	..	0.098
1964-65	..	0.260			

The relatively low loss in the public sector could be considered an achievement brought about by the following methods.

(i) A programme was initiated for putting up better warehouses in the public sector in the year 1960 when the storage capacity in Government owned warehouses was 600,000 tonnes. It rose to 4,700,000 tonnes in 1968 and comprised 4,400,000 tonnes suitable for bag storage and 300,000 tonnes for bulk storage. The bag storage space was designed as rat, dampness and white-ant proof, was provided with facilities that make loading or unloading and stacking easy, and was also provided with arrangements for controlled aeration. The bulk facilities were in the form of metal and concrete silos, equipped with forced aeration, temperature detection and circulatory fumigation arrangements.

Other organisations like Warehousing Corporations and Co-operatives also took up construction of warehouses of the same design as the Government and now a total storage capacity of six million tonnes is available in the country in the public sector.

(ii) Scientific inspection was introduced for all the grain purchased by the Government. This involved laying down quality standards for different varieties of foodgrains, describing sampling and analytic procedures, introducing

scientific tests like moisture determination (in the face of strong opposition from sellers of grain), setting up of grain laboratories, ensuring manufacture of equipment and chemicals needed by the laboratories, and the training of personnel for grain quality inspection work. As against only four grain laboratories in the country a decade ago, in 1968, there are more than 400 laboratories and about 1,000 trained hands capable of carrying out this work in the markets and the laboratories. All the equipment and chemicals required for scientific quality analysis of foodgrains and their products are also being made in the country now. The original standards developed for the Government purchases have been suitably reviewed and National Standards for all foodgrains have been developed for transactions both in the public and the private sectors (Anonymous 1965). The Indian Standards Institution have also published standard techniques of grain sampling and analysis (Anonymous, 1964, 1967).

(iii) With regard to storage management, the following procedures are adopted :

(a) Trained science graduates are provided to ensure proper protection of grain during storage.
(b) Use of dunnage comprising either 0.3 mm. thick polythene sheets or wooden crates that maintain a gap of 15 cm. between grain bag and warehouse floor is made obligatory. Moisture migration brought about by diurnal temperature variations and consequent damage is completely avoided on this account.
(c) All the grain in storage is inspected and sampled by technical personnel at least once a month and is examined and classified on the basis of deteriorative changes, if any.
(d) Treatments such as fumigation, aeration, etc., are planned and carried out promptly on the basis of classification done as at (c) above.
(e) A research institute is set up to solve day-to-day problems and based on the findings of research pilot trials are conducted all over. A number of changes have been made in managerial practices as a result of research findings and the procedures are rendered relatively easy and less costly.

(f) The pesticides required in grain storage work had to be mostly imported. Continuous efforts have made the country almost self-sufficient in this regard, from 1965 onwards.

In 1966 a claim made about large rat population and a loss to the extent of 50 per cent to foodgrains received wide publicity (Parpia, 1965). The Government was prompt in constituting an expert committee to go into the problems of losses. They reported that losses caused to foodgrains during post-harvest handling by various factors were as given in Table 2.

TABLE 2

Loss caused by various factors to foodgrains in post-harvest handling

Stage of handling	*Factor responsible for loss*	*Average loss percentage*
(i) Thrashing yard ..	Birds and rats	1.68
(ii) Transport ..	Birds, insects and rats	0.15
(iii) Processing ..	Birds, rats, insects and mechanical causes	0.92
(iv) Storage ..	Rodents	2.50
	Birds	0.05
	Insects	2.55
	Moisture and microbes	0.68
	Total ..	8.53

Consequently need was felt for intensifying the adoption of better storage methods in the private sector. At present the private sector storage extends to rice-mills that number between 45,000-50,000, roller flour-mills which are around 200, dealers and commission agents whose number is around 700,000, and millions of agriculturists who retain 70 per cent of the produce. Only the first three agencies, namely the rice-mills, flour-mills and the dealers are somewhat organised whereas the agriculturists adhere to the traditional ineffective techniques.

Grain technology : Earlier the deterioration of grain was considered purely an entomological problem. Grain technology has made rapid advances and the quality and deterioration of grain have a different significance today. The intrinsic and extrinsic factors that bring about changes in the composition of grain are now well-understood. Efforts are in progress to develop analytical tests that are capable of indicating precisely the extent of deterioration suffered and the storability of the grain. Sanitary conditions that related to pest infestation and the resultant extraneous matter are receiving increasing attention. These developments assume special significance in India in the context of larger harvests and the increasing activity of food based industries. Marketing, transport and storage are all important in the post-harvest handling of foodgrains.

Marketing : Multicropping and higher yields have greatly affected the traditional marketing patterns. A major portion of the marketable surplus is brought for sale immediately after the harvest when the grain is not well-dried. There is a heavy strain on the available market facilities and most of the sales are made under the price support policy of the Government. Thus the grain is handled by a limited number of agencies. Since the quality inspection, conditioning, weighment, and bagging carried out in the markets are all manual and there is limited man power, these operations are either carried out very slowly or imperfectly. Efforts have been made to overcome congestion in the markets by opening additional markets. With the increase in number of markets, the problem of manpower shortage is only accentuated. Furthermore, new markets are away from the rail heads and there are caused additional needs of transport. Maintaining quality and the mechanical handling of grain could possibly solve the present day problem of disposing off large quantities of grain received in the markets within a short period of time.

Transport : Railways continue to be the main transporting agency for foodgrains. The marketable surplus, which is generally the entire surplus, is to be moved speedily to areas of consumption. Some bottlenecks in transport came to the surface during the last *rabi* harvest season (1968). It is to be appreciated in this connection that the arrivals to the markets were sudden for the first time, and

secondly, the storage construction so far, has mainly been in the distribution areas. Under the price support system there is no higher price offered to compensate for storage charges, and hence burden on the Government or Food Corporation to look after the produce. In case this policy is continued, arrivals to the markets will continue to be almost 90 per cent of marketable surplus, within two months of the harvest. It cannot be expected that the transport facilities be increased only to remove this surplus and then allowed to be idle for the remaining part of the year. What is needed, therefore, is to balance the transport facilities for moving the grain out and to increase the storage capacities in the producing areas.

Presently, all the grain to be transported by rail has to be placed in new jute bags. Otherwise a jute bag is not necessary in the course of handling of grain. The jute bag at the same time increases the cost of handling of grain by Rs. 30-40 per ton. Yet at present all the post-harvest handling of grain is through the bags which could otherwise earn foreign exchange. Moreover, the bagged grain is more prone to damage during storage.

Some efforts have been made in the country to provide bulk transport facilities for grains on railways. It is possible that such a facility would find use only in one direction and the wagons meant for grains only would have to be driven empty on the return journey. However, this difficulty could be overcome by designing suitable multipurpose wagons. In any case the availability of bulk wagons will hasten the process of mechanisation of market operations, setting up of bulk storage facilities and in addition will allow quicker loading and unloading apart from releasing millions of jute bags for better purposes.

Storage developments : In the context of larger harvests of agricultural products, available storage capacity is expected to be insufficient. As far as planning is concerned, the highest priority is being given to requirements of fertilizers and other inputs which are bound to increase agricultural production. It is also apparant that the responsibility for the procurement of foodgrains and holding adequate buffer reserves for meeting emergency situations and also the stabilisation of price will rest with the Government. The respon-

sibility for developing requisite storage will then lie with the Government or alternatively with the public agencies. It is possible that gradually the private sector may take over these functions and here again the Government will have to promote the adoption of scientific practices of grain storage.

Buffer reserves : Establishment of a buffer reserve of foodgrains is a declared policy objective of the Government. Different views about the quantity required have been expressed from time to time. Taking into consideration various aspects such as human population, likely production even in the face of a drought and financial resources available, one group considers a reserve of 10 million as an ideal one. However, a reserve of a magnitude of higher than 5 million tonnes is not considered to be a practical proposition by another group. Viewed from the angle of investment and resources available, a reserve of 4 million tonnes may be the maximum possible. Storage capacity required for a reserve of this size would be of the order of 5 million tonnes. An additional capacity of 2 million tonnes may be considered necessary for pipeline stocks. This consideration is, however, based on present pattern of production. In case there is a further spurt in production and much larger quantities are required to be purchased as a price support measure, the size of the overall storage may need reconsideration.

In India present thinking is to hold the reserves for not more than a year, as longer periods increase the total cost of the grain. In case there is no market at the higher rate, the Government may have to sell at subsidized rates. Although this is understandable, off loading of large quantities of foodgrains in the market when prices are already low could be a discouragement for growing foodgrains in the next crop season. In any case the pattern of disposal will determine the type of grain stores. It is interesting to see in this connection efforts made in surplus countries like U.S.A. and Japan. In the U.S. at one stage the grain had to be stored in holds of ships, where it remained in satisfactory condition, as the ships were anchored in cool waters of the North. It is reported that in Japan, surplus rice is planned to be stored in water-proof containers in the lakes.

In India, so far, storage over 2 years has not been necessary. Longer storage for periods of 3 to 5 years should

not be ruled out in the context of production trends. Fortunately we have now sufficient experience in modern type of silo storage and the related problems as aeration, assessment of quality from temperature records, etc., and safe storage for periods up to 5 years seems possible in the country. This type of bulk storage, that would also eliminate need for jute bags, therefore, seems ideal for maintaining buffer reserves. Only limited storage of this type, however, has been planned. One argument in this connection is the high initial cost of this storage and secondly, its suitability is confined only to foodgrains. A warehouse suitable for bag storage can serve as a multi-purpose store.

Construction costs for bag stores of the modern design is around Rs. 170/- per ton, excluding the cost of land but including the cost of other related facilities like approach roads etc. Somewhat simpler stores of this type could be constructed even at Rs. 120/- per ton. On the other hand bulk facility equipped with mechanical loading and unloading arrangements would cost anywhere between Rs. 180/- to 250/- per ton, depending upon the adjuncts to be provided. These costs presently seem to be high but with cheaper structure designs and competition, the construction cost could be reduced. Moreover viewed on a long term basis, with the lower current expenses, bulk storage is cheaper than bag storage at this cost of construction. Ultimately, when quality considerations prevail, large scale bulk storage equipped with aeration, heat detection, and circulatory fumigation facilities, is going to be the answer for storage problems of commercial stocks. To elaborate this aspect further, merits and demerits of the two types of stores, viz., bag and bulk are given below :

	Bag storage	*Bulk storage*
1. Requirement of land	3 acres for 5,000 tonnes	1 acre for 5,000 tonnes
2. Maximum safe storage Period for wheat	One year	5-10 years
3. Feasibility of mechanical operations	Difficult	Easy
4. Pest control cost per year	Rs. 4-6 per ton	Rs. 1-2 per ton

	Bag storage	Bulk storage
5. Cost of jute bags	Rs. 25-30 per ton	Nil
6. Possible losses :		
(a) Rodents	Can be rodent proof. Otherwise loss 2.5% when pesticidal measures not adopted.	Rodent proof.
(b) Birds	0.05%	Bird proof.
(c) Insects	Can be controlled but cost relatively high. Irradiation technique cannot be employed.	Can be controlled. Irradiation technique can be used.
(d) Moisture	Can be made moisture proof. Some danger always exists.	Moisture proof.
(e) Driage	Inevitable, depending upon initial moisture.	Can be controlled.

Efforts are being made to develop techniques that will enable pest control in bulk stores through mechanical means, thereby eliminating the problem of pesticide residues.

With the large scale adoption of multicropping pattern in agriculture mechanical drying and the conditioning of grain will be necessary. Bulk storage associated with driers or with the provision of in-bin drying will again prove an asset in this connection. Some workers have considered bulk stores unsuitable on account of the possibility of moisture migration in areas of extreme temperature variations. It is our experience that even bag stores are not free of this problem. With the progress made in grain technology and suitable modifications in the storage structure, damage can be completely eliminated without much extra cost. It is interesting that in spite of heavy imports, mechanisation of operations at ports was beset with many difficulties for years. When these difficulties were overcome, it was possible to have faster unloading of much larger quantities at comparatively low costs. Considering various aspects, it would be desirable to plan for as much mechanised bulk storage as

possible out of the 4 million tonnes of capacity that will be created in the Fourth Five-Year Plan period.

A sizeable capacity in the form of emergency storage will also be needed in the next few years, particularly in the surplus areas. Open storage on rodent and damp proof elevated platforms covered with either PVC or polythene sheets can prove very useful. The use of baloon type structures, made of either PVC impregnated fabrics or butel products, which can be rendered air and water tight are under investigation in areas where there is tropical climate and abundance of boring pests like rodents and white ants. If successful, a mobile, effective and comparatively cheap storage facility will be available particularly for use both in the markets and on the farms.

For the farms, programme now under way ,is to popularise the specially designed metal bins, new techniques of insect control, and rat elimination with anticoagualant raticides or aluminium phosphide tablets. Existing practices and new trends are reviewed in the works of Pingale (1961, 1964) and Ram Sivan (1966, 1968). All these techniques have been extensively tried and tested under different conditions in the country before being recommended.

The air-tight steel and aluminium bins at the farms will provide protection from birds, insects, mites, rodents and moisture. In these bins, there is a built-in device for self-aeration and thus moisture migration is avoided. The cost of these bins varies between Rs. 150-250 per ton, depending upon the size. Indoor structures have a flat bottom, whereas, the outdoor structures have a hopper bottom and a pulley at the top to lift the grain to the top opening.

Mixing of inert materials like wood ashes, road dust, etc. have been the traditional methods of protecting grain from insects. Lately, synthetic insecticides have been substituted in place of inert materials. The practice of mixing inert dusts or insecticides are not free of hazards, however. The presence of insecticides on grain can mean either slow or acute poisoning of the consumers, and hence the health standards do not permit mixing of insecticides. Instead, fumigation of grain is permissible, provided precautions are taken to avoid accidents. Ethylene bromide packed in a

glass ampule and enclosed in a cloth bag with some cotton wool has proved highly successful and economical. The glass ampule is broken before it is placed in the grain and the fumigant vaporises. The cost of fumigation comes to Rs. 2/- per ton, which is 0.25 per cent of the price of the grain.

The rats apart from being serious pests of grain are also a great nuisance in the rural areas. Their population is estimated at 7-8 per house (Krishnamurthy 1967). Single doze poisons, trapping and fumigation of burrows with cyanides were adopted for their control earlier. Now cyanides are being replaced by aluminium phosphide which is also being manufactured in the country.

In conclusion it needs to be emphasized that knowledge about grain quality and utilisation has undergone a considerable change and it is necessary that agencies that handle grain during post-harvest period take note of these changes to ensure full utilisation of what is produced with great human effort and investment. Change over to bulk handling in place of bag handling will facilitate mechanisation of operations which in turn can accelerate greatly the holding procedure, and will also ensure protection from deterioration over long periods. The change over will be rendered easy by devising simpler and cheaper structures and techniques. A beginning has been made in respect of farm storage by the popularisation of metal bins. Adequate arrangements have also been made for training the staff who test and handle grain. A lot more will have to be done as the impacts of new varieties and multicropping patterns are just being felt. Those will have far reaching effects on national outlook and economy. We must think ahead and be prepared for more changes.

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Environmental Regulation for the Control of Stored Grain Pests

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Introduction : Strenuous efforts are being made in India to increase food production so as to meet the deficit and make our country self-sufficient. The protection of food in storage from the ravages of insect pests, mites, rodents, micro-organisms and dampness also needs an equal emphasis. The annual losses to foodgrains during post-harvest handling and storage as recently estimated by an expert committee constituted by the Union Ministry of Food and Agriculture, stand as high as 9.33 per cent (7.3 million tons worth Rs. 584 crores) (Anonymous, 1967). About a dozen insects infesting stored products often assume pest status in different parts of the country. The major species found in cereal grains and other products are rice weevil (*Sitophilus oryzae*), lesser grain borer (*Rhizopertha dominica*), *khapra* (*Trogoderma granarium*), rice, moth (*Corcyra cephalonica*), Angoumois grain moth (*Sitotroga cerealella*) and red flour beetle (*Tribolium castaneum*). The pulses are also attacked by a number of species of the family Bruchidae (Pruthi and Singh, 1950).

The storage pests are considered to have originally been pests of field crops from where they seem to have gradually moved to stores and adapted to the new but less hazardous environment. Most of these insects were of tropical and subtropical origin (Cotton, 1963), where wheat, barley and rice were the principal grain foods. Owing to their

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small size and the ease with which they could conceal themselves in grain, these insects were distributed to all parts of the world through commerce. The climatic conditions everywhere were not equally favourable, so the species which were of major importance in some countries could barely exist in others. For example, the *Khapra* beetle, *T. granarium* which is a major pest of stored grains in India could get established in south-western states of America only recently, although it has probably been introduced a number of times.

The infestation of stored products is not conspicuous until severve damage has already been done. Losses to stored grains are also masked to some extent by the gain in weight through absorption of moisture, particularly during the rainy season. The losses in weight, nutritional value and germination capacity of seeds can be minimised by the application of improved technology in handling and storing foodgrains. The knowledge of modern handling and storage is generally derived from highly industrialized countries. In India, it is applicable only to the commercial storage conditions and not to rural areas. Thus the fumigation of stored grains although quite effective, is not applicable under the prevalent conditions of storage. The chemicals recommended for mixing in the grain can safely be used in grains meant for seed only.

Due to the limitations of chemical control, many scientists have realised that the control of storage pests is basically an ecological problem which calls for a systematic attempt at understanding the factors responsible for fluctuation in pest populations. What is needed is to take measures aimed at keeping the pest populations below the economic threshold. A population, as defined by Huffakar (1964), is the function of interaction between innate qualities of a species and the effective attributes of environment in which the population is both supported and limited numerically. The fitness of the function can be reduced by either modifying the innate qualities of the organism or changing the environment or by both the methods (Geier, 1966). It is in this context the it is proposed to analyse the problem of control of insect pests of stored grains.

Environment of stored grains : It is very important to

understand the concept of environment. According to Platt and Griffths (1964), the functional environment of a specific organism is not the generalized environment or climate but it is something composed of continuously changing complex of all conditions and influences which are interacting with that organism. If we follow the general classification of environment into abiotic and biotic factors, the abiotic environment of storage pests comprises the physical factors, namely; temperature, moisture, oxygen and carbon dioxide content, light, radiant energy, gravity, pressure, sound, etc.

The biotic environment of storage insects consists of food, its quantity and quality; population level of the species; interaction of the pest population with other species including parasites and micro-organisms.

The influences of different components of environment are interrelated in a number of ways. The living organisms interact with each other and are inseparably interrelated with abiotic environment. These interactions can be categorised as follows :

1. Interaction between individuals of the population in regard to, birth rate, age distribution (proportion of different stages), dispersion, etc.
2. Interaction between different species as they strive for something in short supply, e.g. food and space.
3. Negative interaction between speices such as predation and parasitism.
4. Positive interaction between speices : commensalism, etc. Some species like *Tribolium casteneum* are not able to bore into the sound grain but depend on others like *Sitophilus oryzae* for opening the way for their infestation.
5. Interaction at the community level include dominance by one or more species, which control habitat, succession and periodicity.
6. Interaction with aboitic environment, e.g., effect of stored grain insects on the micro-environment through change in temperature, moisture etc. as the insects are responsible for heating of grain and transfer of moisture.

Measurement of environment : To study the effect of

different components of environment, it is important that those are measured accurately. The factors which can be easily measured are, temperature, humidity, oxygen content, light, etc. All these are, however, so closely bound that it is difficult to assess the part played by each one except under controlled conditions. Nevertheless the measurement of these components in the natural environment is necessary to record the variations in level. The measurement of insect environment and micro-climate of stores has been made easier and surer by the recent developments in electronics, particularly by the development of minute semiconductor elements, thermistors, transistors and diods which have the advantage of small size, reliability, robustness and the extremely simple and portable battery power supplies required (Munro, 1966). The use of these instruments is not yet extensive. Siddorn (1962) describes various miniature instruments for measuring temperature, humidity, air movements and Platt and Griffths (1964) have comprehensively dealt with the measurement of environment in general. There is a great need to work on this aspect and devise instruments for measuring environment of stored grains, keeping in view our conditions and needs. For example, simple instruments for measuring moisture, temperature of grain at different depths in bulk storage, concentration of Co_2 and O_2 in a given type of receptacle can be of great help in the study and analysis of environment of stored grain insects.

Effect of environment on innate capacity for increase : The power to increase in numbers in favourable conditions is inherent in all organisms. The species, however differ in their innate capacity to increase (rm.). The innate capacity for increase as defined by Andrewartha and Birch (1954) is the maximal rate of increase attained at any particular combination of temperature, moisture, quality of food and so on, when the quantity of food and other animals of the same kind are kept at optimum and other animals of different kinds (i.e., parasites and predators) are excluded. In other words, the innate capacity is the infinitesimal rate of increase of a population with a stable age distribution, i.e., when the proportion of different developmental stages is constant. The innate capacity and other such statistics give an approximate measure of actual characteristics of species concerned, which enter fundamentally into its population dynamics, however, greatly their expression is modified in nature. The

success of insects which make a fresh start in the beginning of each crop season may depend to a great extent on their ability to multiply quickly. Similar conditions are prevalent in warehouses and granaries where there is periodic removal of grain or where the insects become almost inactive due to low temperatures in the winter season. The innate capacity for increase has been worked out in respect of some storage insects by Birch (1948), Leslie and Park (1948). Howe (1953) compared the capacities for increase in nine species of Ptinid beetles infesting stored grains in Britain and found that *Ptinis tectus* with the highest capacity for increase at 25°C was by far the commonest of all. That the high rate of increase is advantageous to a species in eliminating another species with low rate of increase at a particular temperature and moisture content, has been proven by Birch (1953) with his laboratory studies on *Rhizopertha dominica* and the two strains of *Sitophilus oryzae*. Laboratory experiments were carried out at Ludhiana to work out innate capacities of some stored grain insects. At 30°C and 70 per cent Relative Humidity the following results were obtained :

TABLE 1

Innate capacities of some stored grain insects at 30°C and 70 per cent R.H.

Name of insect	*Food*	*Innate capacity for increase (rm)*	*Finite rate of increase per day*	*Times population is expected to increase per week*
Callosobruchus analis	Moong	0.154	1.17	2.89
Pachymerus chinensis	Gram	0.086	1.09	1.79
Trogoderma granarium	Wheat	0.119	1.25	2.28
Sitotroga cerealella	Wheat	0.097	1.12	2.22
Corcyra cephalonica	Maize	0.0593	1.06	1.50

Trogoderma granarium has a somewhat higher innate capacity for increase than *Sitotroga cerealella* on the same food (wheat) at the same temperature. So, it is expected to be dominant if the two populations start increasing together in the same grains. *Khapra* is known to eliminate other insects in the stores under the conditions prevalent in drier parts of the Punjab.

Since the insect-pests of stores live under fluctuating

conditions of temperature and humidity, the index of 'rm' is, therefore, not directly applicable. However, it shows the comparative status of various pests.

(A) *Effect of abiotic factors of environment on the storage insects :* The abiotic or physical factors like temperature, humidity, moisture content of the grain, oxygen content, light, etc. may act directly on the insect or indirectly through the food stuffs. Of the direct effect of climate, the most important is its influence on the geographical distribution of a pest. In tropical countries, the storage insects live in a stable and uniform climate but in temperate countries, they are subject to greater extremes of temperature. Thus low and high temperatures to a large extent limit their distribution. The physical factors of environment also vary in different types of storage of foodgrains. Before we discuss the environment in a particular type of receptacle, it is important to know as to how the different components of environment influence the survival, development and multiplication of different storage insects. The effect of various factors is, therefore, discussed separately.

(a) *Temperature :*

(i) *Effect on development and survival :* Temperature is the most important factor of the abiotic environment and it controls the rate of metabolism, growth, development, general behaviour and distribution of insect pests. The speed of development has been measured at different constant temperatures in case of several stored grain insects. In their natural environment in godowns, the stored grain insects are subjected to fluctuating temperatures, which may be considered as equivalent to a calculated constant temperature (Andrewartha, 1961). When the fluctuations include extremes outside the favourable range, there are two possibilities :

(1) A short exposure to an extreme temperature may impair the insects' competence to develop at favourable temperature.
(2) Healthy development may be possible after short exposures and be harmful if prolonged.

The favourable and optimum range of constant

temperatures and relative humidity of a number of storage insects is given in Table 2.

TABLE 2

Favourable and optimum temperature and humidity for the development of some storage insects

Name of insect	*Stage*	*Range of favourable temperature* — *Lower limit*	*Upper limit*	*Optimum temp. and R.H.*	*Reference*
Corcyra cephalonica	All stages	..	39°C	30°C×70/90% R.H.	Kalkat and Sohi, 1960
Rhizopertha dominica	-do-	..	39°C	33-36°C× 70-90% R.H.	Bains and Singh, 1961.
Pachymerus chinensis	-do-	..	39°C	30°C×70% R.H.	Singh, 1964
Tribolium castaneum	Immature stages	20°C	40°C	30°C×70/85% R.H.	Grewal, 1964
Sitotroga cerealella	All stages	..	..	30°C×80% R.H.	Grewal, 1963
Trogoderma granarium	-do-	25°C	40°C	30-35°C×13% moisture content	Sukhija, 1965
Sitophilus oryzae	-do-	..	..	29.C×14% moisture content	Birch, 1945

Studies made at Ludhiana (Table 2) show that the optimum temperature and relative humidity for the development of common storage insects lies between 30-36°C and 70-90 per cent R.H. The optimum temperature for *T. granarium* and *R. dominica* are higher than other insects. The lower and upper limits of favourable temperature for most of the insects range between 20-25°C and 39-40°C.

Effect of lethal low temperature : The development of storage insects is inhibited at temperature below the threshold

of development and if they are subjected to still lower temperatures, the effect is fatal. Records of the relative susceptibility of various stored grain insects to low temperature are given in Table 3.

TABLE 3

Low temperature resistance of various insects that attack stored grains (Cotton, 1963)

Insect	*Days exposure required to kill all stages at*						
	0-5°F	5-10°F	0-5°F	5-10°F	20-15°F	15-20°F	20-25°F
Rice weevil	1	1	1	3	6	8	16
Granary weevil	1	3	..	14	33	46	73
Sawtoothed grain beetle	1	1	3	3	7	23	26
Red flour beetle	1	1	1	1	5	8	17
Confused flour beetle	1	1	1	1	5	12	17
Indian meal moth	1	3	5	8	28	90	..
Mediterranian flour moth	1	3	4	7	24	116	..

Temperatures that are not immediately lethal indirectly cause the death of many insect-pests by rendering them inactive and preventing their feeding. Since most of the insects do not hibernate, their life processes are not sufficiently retarded by low temperatures; but the food reserves get exhausted and they die of starvation. A very low temperature as -17.8°C is lethal to most of the stored grain insects (Girish, 1965).

Effect of lethal high temperature : The limit of lethal high temperature differs not only for species of insects but also for different stages of the same species as may be seen from some records given in Table 4.

TABLE 4

Effect of lethal high temperature on some storage insects

Insect	*Stage*	*Temperature*	*Exposure*	*References*
S. oryzae ..	Adult	35-36°C	9 days	Back & Cotton, 1934
-do- ..	Adult	47°C	10 minutes	Grossman, 1931
-do- ..	Eggs	34.6°C	..	Birch, 1945
R. dominica ..	Adults	71°C	..	Dendy & Elkington, 1920
-do- ..	Eggs	40°C	..	Birch, 1945
T. granarium ..	Adult	50-51°C	5 hours	Hussain & Bhasin, 1921
T. castaneum ..	Adult	49°C	30 minutes	Grossman, 1931
-do- ..	Eggs	40°C	..	Howe, 1956
S. cerealella ..	Adults	49°C	10 minutes	Grossman, 1931
-do- ..	Larvae	60°C	1½ hours	Harukawa & Kumashiro, 1942
-do- ..	Larvae	70°C	30 minutes	-do-
-do- ..	Larvae	80°C	15 minutes	-do-

(ii) *Effect on reproduction and longevity :* The threshold of reproduction which is defined by Rivnay (1951) as the temperature below which, courting, mating and oviposition do not take place, is a little above the threshold of development.

Grain temperature of 70°F (21.1°C) is considered to be the danger line for reproduction because at or above this temperature, damage from insects to stored grains is expected. Below this temperature level, no serious damage is likely to occur (Cotton, 1954). With a few exceptions temperatures above 35°C are unfavourable for reproduction as oviposition ceases and adults are short lived. The lesser grain borer is one exception, reproduction in whose case has been recorded at 100°F (37.4°C) by Gay and Ratcliff (1941).

(b) *Moisture :* The storage insects depend on their food supply for moisture requirements. The grain moisture is, therefore, an important factor in their life

economy. Increasing the moisture content up to a certain point favours a rapid increase in the number. If the moisture is low, the water required for vital life processes is obtained by breaking food reserves in the body. The ability to produce this metabolic water differs in various storage insects and accordingly moisture requirements through foodgrain also differ. The rice and granary weevils are unable to breed in grain with a moisture content below 9 per cent because they cannot increase their water level of the body by the use of metabolic water.

According to Cotton (1954) the maximum numbers of rice weevils are found in 14 per cent moisture content at 80°F. As the temperature was increased from 70°F to 90°F the ability of the weevil to reproduce in dry grain increased. The lesser grain borer breeds in wheat containing 8 per cent moisture. The flour beetles are less dependent upon the moisture content and are able to breed in flour from which practically all moisture has been removed. The high moisture content in grain is nevertheless more favourable for their survival and reproduction (Cotton, 1954). The larvae of the moth *Ephestia* can live in flour that has been dried in an oven at 105°C and stored in a desiccator over concentrated sulphuric acid (Andrewartha, 1961). It has, however, been observed that most of the species maintain a relatively high level of water in their bodies, if they are to remain alive, irrespective of moisture content of the foodgrains. The moisture content requirements of the common storage insect as worked out by different workers are given in Table 5.

TABLE 5

Moisture content of grain at which different storage insects can breed

Insect	*Minimum moisture requirements**	*Optimum moisture requirement**
S. oryzae ..	9.5-11%	13.2-17.6%
R. dominica ..	5-8%	11-14%
T. granarium ..	0-1.9%	2-15.7%
C. cephalonica ..	5-8%	12-17%
S. cerealella ..	5-8%	12-17%
T. castaneum ..	10-12.2%	11-14.2%

*These figures represent the range in which the findings of different workers vary.

The available information about the moisture content of grain especially the lower limit that permit development of a given insect is not consistent and the workers differ in their findings on the same insect. Although temperature is an important factor which influences the lower limit, and has not always been taken into consideration, yet it is likely that more is involved than the variation in temperature. The two major possible sources of error common to such investigations are :

1. The technique of measuring moisture content of grain.
2. The practice of measuring moisture content only at the beginning of the test on the assumption that even with insects multiplying such grain would retain a moisture content in equilibrium with the relative humidity of the surrounding air.

Some authors took moisture on the dry weight basis and others on wet weight basis making no mention of the method used. The result has been that at the same relative humidity different moisture contents have been worked out for a given grain by using different methods. It is, therefore, important that some tested and standardised method is used. The two stage air oven method is considered to be one of the best methods (Agarwal, 1964).

Robinson (1926) showed that when rice and granary weevils were breeding the moisture content of grain increased from 13.5 to 19.3 per cent. The recording of moisture content at different intervals throughout the test, is, therefore, very important. Chatterjee (1953) and Danial (1956), however, ignored this point and carried out their studies at 75 per cent R.H. which they considered was equivalent to 12 per cent initial moisture content. Whereas the importance of moisture content of grain for multiplication of storage insects has been emphasized by most of the workers, some of them, namely Eastham and Segrove (1947) and Chatterjee (1953) believe that relative humidity of the inter-seed air generally plays even a more important part in insect activity than the initial moisture content.

(c) *Oxygen content :* Each insect species requires a particular minimum concentration of oxygen for existence. The minimum concentration of oxygen required by different

stages of species has been determined by confining than, in air-tight containers, and analysing the oxygen content when all the individuals are dead. In case of *Tribolium castaneum* the lethal oxygen for full grown larvae and adults was 6.37 per cent and 7.24 per cent, respectively (Sinha, 1965). The eggs of *T. granarium* were dead at 16.77 per cent oxygen but concentration of 1.082 per cent was lethal for full grown larvae. For the adults the lethal level was 3.39 per cent. It is indicated that further multiplication of a particular species will stop as soon as oxygen content goes below the level required by the most susceptible stage even if it fulfills the requirement of other stages, i.e. *khapra* would not multiply if oxygen content went below 16.77 per cent. This insect has the capacity to multiply even at low moisture content of grain (about 2 per cent m.c. is the minimum required) but can, be controlled by proper manipulation of oxygen content and carbon dioxide concentration.in the respectables.

(d) *Light :* Almost all the stored grains insects shun light and they have a tendency to shelter in crevices. In other words, they are negatively phototactic but are generally positively thigmotactic (Munro, 1966). The effect of light on the multiplication of storage insects has not received much attention. Rahman and Sohi (1939) and Sohi (1961) studied the reaction of *khapra* beetle to sunlight and effects of constant light and darkness on the development, reproduction and food consumed. According to their reaction to light, adults and grubs of *khapra* were grouped under categories (i) photonegative (ii) photopositive (iii) indifferent. The one day old grubs were not affected by light but as they advanced in age they became photonegative, changing their reaction before and after moulting. The majority of ovipositing females were photonegative. These findings explain the phenomena as to why the attack of *khapra* is more serious in heaps of grains which are in dark or in the bagged wheat kept in the darker and concealed places.

The response of *Ephestia* moths to day-light as observed by Ghadiok (1965) was also negative. It was studied that the incidence of *Ephestia* sp., remained low for three years in a godown covered with translucent plastic corrugated sheets on the upper side which allowed light to pass through.

Effect of various abiotic factors on the distribution of insects in godowns : The distribution of insects in bulk grain is influenced by a number of factors. The moths being fragile and weak are unable to force their way through grain and, so in their case infestation is largely confined to the surface. The weevils and flour beetles on the other hand can move freely through the grain. The distribution of these insects appears to be influenced largely by temperature and moisture.

The effect of temperature on insect distribution is different in large storage and in small bins. High temperature in the middle of the grain as generated by insect metabolism either kills or drives the insects to cooler grain at the surface. In U.S.A. the insects in wheat stored in small steel bins were found to be in the upper half of the bin during Spring, and Autumn, but in the lower half in mid-winter. In mid-summer the insects in the bin were usually uniformly distributed (Cotton, 1954). Other conditions being equal, the storage insects would be attracted to damp portions of the grain heap.

The behaviour of individual insects resulting in aggregation in restricted parts of the habitat (accumulation) and spatial distribution of population (dispersion) is generally influenced by the population density,in addition to temperature and humidity. For example, the dispersion of *Oryzaephilus surinamensis* is almost entirely determined by kinesis mechanism and the accumulation takes place in the warmest and dampest part of a grain heap (Gordon, 1963). The dispersion of *T. castaneum* is, however, determined to a lesser extent by kinesis mechanism; accumulation takes place in the drier parts of bulk and at places where temperature is about 25°C, but also in regions of damp mouldy grain. *R. dominica* accumulates in the driest parts of the grain bulk. A knowledge of the underlying causes of dispersion and accumulation thus aids in detection of the pest in addition to giving an idea of the optimum storage conditions.

(B) *Effect of biotic factors on multiplication of storage insects :*

(i) *Food :* Food supply is the most important factor

of the biotic environment of storage insects governing their increase. Only certain foods meet the specific requirements of a particular species of insects. Although most of the storage insects can develop on a number of alternate foods yet the best food is the one that is preferred. Thus the quantity and quality of food may influence the fecundity, longevity, and speed of development of the insects. The needs of various species of insects for nourishment play an important role in determining the composition of insect population in godowns. It has, been demonstrated in case of *C. chinensis* and *R. dominica* that they do not follow Hopkin's principle of host selection, i.e. they do not prefer to breed in the host in which they develop (Crombie, 1941, Zaaou, 1951). Studies on the oviposition behaviour of *C. chinensis* showed that the texture of the seed coat was related with preference, but the oviposition preference did not seem to have any relation to the suitability of food for development because the seeds of French beans and field peas although preferred for oviposition were unsuitable for development (Teotia and Singh, 1966). The same authors found that the ratio of females to males was generally higher in more nutritious host seeds. In general, the bigger the size of the host the larger were the beetles produced.

In the winter when the stores are emptied in Northern India, the insects can hardly breed although they live in cracks and crevices. Most infestations originate after grains are placed in storage, and the receptacles are the main source of infestation, although some of the beetles and moths e.g. *R. dominica*, *S. cerealella*, do reach the godowns by flight.

The factors of nutrition and availability of food sometimes so operate, as to modify the effects of relative humidity and temperature. For example, when grain is milled, food is available in a form that can be utilized by immature stages of those insect species that are unable to breed in undamaged grain.

(ii) *Interactions with other organisms :* The density of population of individuals of the same species may be (i) optimum (ii) under populated (iii) crowded, and the rate of increase in numbers may vary accordingly. For

example, the rate of multiplication of *T. confusum* is slow when there are a few beetles in the population but increases to the maximum as the density of population approaches an optimum. Park (1933) explained that it was due to the sexes meeting less frequently, resulting in reduced number of eggs. Secondly, the existing insects were able to ameliorate the environment. It is also known, for instance, that *R. dominica* cannot be established in laboratory cultures of sound wheat unless a large number of insects are put together in the same jar (Andrewartha and Birch, 1954).

In favourable environment, if food and space are unlimited and a population of an insect species has attained a stable age distribution (constant proportion of different stages) the population is expected to go on increasing at maximal rate (=rm) (Andrewartha and Birch, 1954). But in nature the state of the population is often complicated by the changing food resources, weather factors and space. In storage insects the effect of crowding is often manifest even when food, space and weather factors are not unfavourable. For example, Park (1948) reared a number of populations of *T. confusum* and *T. castaneum* giving optimum food, temperature and moisture for 70 generations, but the number of beetles never exceeded a particular number and the populations showed oscillations. The effect of crowding was explained by two factors :

1. Conditioning of flour due to excrement and its reduced nutritive value;

2. Adults and larvae fed on eggs and pupae in crowded population.

The interactions are even more complicated when there are more than one species living together in the same receptacle. The interaction between two species can be of five sorts (Slobodkin, 1961) :

1. Two species may compete for same resources of the environment and one may be eliminated;

2. The first species may serve as environmental resource for the second;

3. The second may serve as environmental resource for the first;
4. The two may be of mutual benefit;
5. The two species may have nothing whatsoever to do with each other.

When there are a large number of species interacting one or more may dominate the community, depending upon the complex interactions of various factors.

(C) *Parasites, predators and diseases* : The parasites and predators are known to suppress host population to a considerable extent. However, the biological methods of control have not been successful in case of any storage insect due to the following reasons :

1. The presence of parasitic wasps in grain and other commodities is as objectionable as the presence of pests themselves.
2. Although a number of hymenopterous parasites have been recorded on storage pests they do not reduce the host population significantly.
3. The stored grain and other food commodities are frequently moved and disturbed and the delicate hymenopterous parasites probably fail to survive the disturbance, while their host beetles are less affected.
4. Some species of mites attack insects but their activities are more destructive to laboratory stocks than in the field.
5. The fungal and bacterial infections of grain pests in warehouses do not give good control. It was observed that 90 per cent of the Ephestia caterpillars in a warehouse were infected with *Bacillus thuringiensis* and yet the host population maintained itself at a high level (Richards and Waloff 1946).

Effect of storage pests on the environment : An interesting feature of the stored grain pests is that not only are they influenced by the environment but also they are themselves capable of influencing their environment. They can increase the temperature and moisture content of grain to a marked extent. When insects are in large numbers the

accumulation of metabolic, heat in the surrounding grain causes hot spots or areas where the temperature of the grain may rise as high as 42°C. Even when the moisture content of the infested grain is comparatively low, a musty odour results from this heating. Moreover, through the translocation of water vapours from warm region to cooler areas grains are dampened and cakes are formed. Due to the absorption of excessive moisture by grains the rate of respiration is increased which produces more heat. Heat from the radiating points travels to cooler parts in the grain mass, carrying along with it a high moisture which is then condensed. With the increase of moisture in these new spots the rate of respiration is again accelerated and the original cooler parts are thus heated. This phenomenon of transmission of moisture from one part to the other and the subsequent heating continues in a cycle. Excessive heating may result in cake formation and the attack of fungi. It is to overcome these difficulties and losses that mechanical devices for the regulation of temperature and moisture have to be installed in large sized bins or grain elevators. Without such devices naturally the size of the bins has to be limited.

Control of storage pests : Having discussed the possible effects of different components of environment affecting stored grain insects, we are now in a position to consider the manipulations of the environments so as to suppress the multiplication of pests and maintain the numbers below the economic threshold. This can be achieved by applying the following principles :

(i) Modification of innate qualities by burdening the population with useless individuals. This is achieved by sterilizing the insects : (a) sterilizing with ionising radiation. (b) use of chemosterilants. (c) exposure to electronic flashes.

(ii) Modification of environment by :

(a) Increasing the severity and frequency of natural hazards, e.g. use of low and high lethal temperatures to kill stored grain insects.

(b) Preventing pest species from locating vital requisites such as food. This can be achieved by either repelling or preventing the entry of insects with the good grain.

(c) Curtailing the supply of vital requisites and making the habitat unsuitable for the species, e.g. disposal of grains; treatment of godowns to kill insects; curtailing the availability of oxygen and increasing CO_2 by making stores air-tight.

The modification of innate qualities of the pests to reproduce have somewhat limited scope in the control of storage pests and it is not proposed to discuss them in detail. The modification of environment on the other hand has a great scope and needs much more attention than it has received hither-to-fore.

Modification of environment : The aim of altering the environment is to make it less favourable and thus lower the carrying capacity of the insects. The environment of stored grain insects can be manipulated to a great extent. Such manipulations are not altogether new but these had been in vogue without understanding the full implications and effects. For example, exposing the grains to sun, turning and screening of grains to avoid heating and air tight storage in underground *khattis*, used to be practised in rural areas of India from quite early times. The control measures based on manipulation of physical environment have evoked great interest in recent times even in the industrialized countries. Exposing of mills to sub-zero temperatures in North America has been successfully employed. The air tight underground storage in Argentina and parts of Africa for conservation of grains over a long period has given encouraging results. The non-radiant heat and radiant energy has been made use of in recent times for the control of insect-pests of stored grains in more industrialized countries. The situation needs thorough analysis so as to make use of all such methods under our own conditions of storage which differ from those of industrialised countries. Nearly 60-65 per cent of the grains are stored by producers in small receptacles of varied types which need improvements.

While analysing the grain storage problems in India Pradhan (1968) rightly emphasized that for safety of the grain from insects, the three most important factors of environment, viz., moisture content of grain, availability of oxygen, and development of temperature gradient have to be properly manipulated, firstly, through

the design and construction of storage structures and godowns, and, secondly, through storage practices. If, however, these ecological safety measures are not practicable, then recourse to chemical and physical methods becomes necessary.

The environment in relation to control can be discussed under the following :

1. Storage structures.

2. Storage practices.

3. Physical control measures.

1. *Storage structures :* It is a well-known fact that the environment in different types of receptacles differs. The foodgrains if left open to weather tend to acquire the prevailing temperature and humidity. It is the degree of their exposure to atmospheric weather conditions that determines the environment created subsequently, particularly when kept in a receptacle. The purposes of grain storage in receptacles are :

(i) not to allow damage by insects.
(ii) not to allow deterioration in quality of grain.
(iii) not to affect germination power of grains required for seed.

None of the receptacles presently used in India satisfy these aims. Efforts to improve the types of receptacles already in use by standardizing their structure have been made. Code of practices for the construction of different types of storage structures have been prepared and published by the Indian Standards Institution. About fourteen such standards are available and the recommended types differ for the five climatic regions of India. It is not possible to discuss here the merits and demerits of each type of receptacle but it is proposed to discuss the variable types of environment of stored grains available in rural areas.

(a) Airtight storage versus ventilated storage.
(b) Bag storage versus bulk storage.
(c) Underground storage versus above ground storage.

(a) *Airtight versus ventilated storage :* Airtight storage is now recognised as an important and effective control measure against insect infestation in grains. The scientific principle in hermetic or airtight storage is the depletion of oxygen brought about by the respiration of the grains, the insects, and the microflora present there. In such structures, insects may die for want of oxygen, due to high temperature or excessive concentration of carbon dioxide. As grain is also living material completely airtight conditions for an indefinite period are likely to deteriorate the grain if oxygen gets completely exhausted. Under practical conditions, however, it has been demonstrated that insects die long before oxygen gets completely exhausted and, thereafter the grains which consume very little oxygen can remain healthy for quite long periods provided the moisture content is not higher than 10 per cent. As mentioned earlier, the lethal oxygen level varies for different stages of storage insects. Recent studies made at the Pest Infestation Laboratory Slough (U.K.) indicate that the oxygen concentration level of 2.5 per cent is lethal to most insects if the re-entry of oxygen is less than 0.2 per cent by volume per 24 hours. So there is a possibility that the structures which are not completely airtight but fulfil the conditions pointed out above may also serve as hermetic storages for all practical purposes (Hyde, 1962). In the airtight storage there is no increase in moisture content from outside sources and the grains are safe not only from damage by insects but also from the bad effects, of dampness, heatspots and micro-organisms. Investigations on airtight storage both with dry grain and damp grain (Hyde and Oxley, 1960) have shown that with grains of 13.5 per cent moisture content even the infestation present before storage is killed; and dry grain can be maintained for quite long periods without deterioration in quality or germination capacity. Damp grain with 16-17 per cent moisture content, however, deteriorates in time. Grains with 24 per cent moisture when kept in airtight storage at 25°C entirely lost the germinating capacity after six weeks.

Ventilated storage on the other hand provides good environment both for the insects and the grains, and the insects multiply quickly in favourable environment and damage the grains, unless disinfestation is done. Despite this, opinion in favour of ventilated storage was expressed by a number of specialists in the past. Brown

(1919) reported that at Peshawar grains remained safe if kept in airy stores. Fletcher (1923) confirmed this report in respect of *T. granarium*. It might have been due to greater variation of temperature in ventilated stores at that particular place. Bhasin (1923) observed that airtight conditions did not work under large scale storage as he failed to make some pitchers airtight even with wax coating. It was thought that when the storage conditions were such that the airtightness was not enough to keep the pest infestation low, then it might be better to keep the stores thoroughly ventilated which would also reduce the chances of development of heat spots. But with the advancement in knowledge and development of suitable techniques, it should not be difficult to make the storage receptacles airtight to the desired extent. More experimentation for rural conditions with improved storage receptacles is the need of the hour.

(b) *Bag storage versus bulk storage :* The bag storage is in vogue mainly because of the ease in handling and transporting grain. Otherwise, the grains stored in gunny bags are more exposed to insect infestations. The bulk storage has been considered preferable to bag storage by all those workers who studied this aspect (Cone, 1945; Pruthi and Singh, 1950; Sontakay, 1950). In bagged grain the heat produced by insect activity is dissipated through inter-bag space and does not get built up to a level when it can limit insect activity, whereas, deeper layers of grain stored in large bulk are near to the airtight storage. Thus, it results in the reduction of infestation which tends to remain confined to the periphery. The storage structures constitute the most important single factor in keeping the grain free from spoilage.

(c) *Underground versus above ground storage :* The underground cellars known as *khatti* or *banda* have been in use in India for long term storage of foodgrains especially in central and southern part of India where the sub-soil water is low. In some parts of U.P. *khattis* as old as 100 years have been observed (Pruthi and Singh, 1950).

Although these pits are not completely airtight and waterproof but they are lined with straw or other absorbent material which by becoming moist and mouldy deplets the intergranular air of oxygen so that any insects if present are killed.

3. It should be fitted with aeration facilities for cooling.
4. The walls of the container should permit limited access of oxygen from the atmosphere by diffusion, so that insects would be killed in low oxygen.

(b) *Storage practices :* In any type of storage structure some faulty storage practices may result in creating favourable environment for storage pests. As mentioned earlier, moisture content of grain is one of the most vital factors and if grain with initial high moisture content is stored, it is bound to suffer. Storage of grain with low moisture content will restrict insect activity and the maintenance of low moisture content will ensure safety of grains. In dry months, the grains can be dried directly in the sun but a suitable grain drier should be provided for each godown. The problem of drying grain has been discussed in detail by Oxley (1950). Comparable work for Indian conditions is lacking. Suitable methods for drying the grain under our rural storage conditions need to be developed.

(c) *Physical control measures :*

1. *Use of heat and cold :* The value of heat treatment and refrigeration have been known for many years. The heat of the sun was utilized in early times for killing insects in grain. Probably these observations on the effectiveness of solar heat later led to the artificial methods of sterilization of grain and cereal products. Sterilization of flour-mills by heating was first used in U.S.A. in 1914. Installation of a special heating system is involved and once capital expenditure incurred, this method compares favourably with fumigation (Cotton, 1963). It is essential that a temperature of 120-130°F is maintained for a period of 10-12 hours. In recent years unit heaters have been developed that require no elaborate piping system and raise the temperature rapidly and uniformly by forced circulation (Cotton, 1963). Raising temperature of warehouses to a level lethal for insects by bringing charcoal has been recommended in India but in practice it was found not workable. Insects vary in their resistance to high temperatures but a temperature of 140°F for ten minutes is fatal to all grain infesting insects (Cotton, 1963). The grains however afford a certain amount of protection to insects so a higher air temperature is needed, or the exposure may be prolonged. According to Hurst

Whereas the *khatti* once popular in India is getting obsolete, it is interesting that this type of storage is getting popular in Argentina (Hyde, 1962), where millions of tons of grains are stored in this way. The tests carried out on pit storage in parts of Africa with dry grains for long term storage gave encouraging results but if moisture content was high (16-17 per cent) the grain became somewhat unpalatable. When grain is stored in 60 tons capacity airtight pits a fairly high initial infestation of the rice weevil is killed after two months (Hyde, 1962). Sheshagiri (1958) considers it worthwhile making improvements and popularising this type of cheap structures in this country but there are difficulties in areas where water-table is increasing through increased irrigation.

The receptacles used for above ground bulk storage in rural areas include mud bins (*kothis*) *pucca* bins (*bukhari*), straw bins, bamboo bins, earthen receptacles, metal bins, drums, etc. (Pruthi and Singh, 1950). All of them are neither insect proof nor airtight. Insects like *R. dominica* work their way through the mud that is plastered over the receptacles (Fletcher and Ghosh, 1921). When *S. oryzae* also gets entery, in addition to the losses by feeding, it causes the entire quantity to ferment and rot. In vessels that are left open to free air, although infestation takes place, there is no fermentation and rotting of grain. Pingale and Balu (1955) observed that in the non-airtight storage receptacles, losses due to insects and microbes are minimized when the heat produced is allowed to accumulate and the moisture given off is allowed to migrate out of the receptacle. They feel that earthen vessels satisfy these requirements and can be recommended to the producers after making suitable changes. Providing those vessels with polythene lining has been suggested by Pradhan, *et al.* (1959). Such studies have been made on low moisture wheat and with single insect species. Polythene lining will help retention of temperature but also prevent dissipation of moisture for which polythene lining of lower thickness may be more effective but then it may become prone to entry by some insects like *R. dominica*.

Wooden bins are not termite and rodent proof besides being not fire-proof. Metal bins of aluminium although insect proof, cause spoilage through moisture migration (Mjumdar and Natrajan, 1963). Most of the above ground

and Black (1930) an air temperature of 180°F is considered the maximum allowable temperature for drying wheat without injuring the milling and baking qualities. The germination of cereal grains is not impaired at the temperatures 120-130°F.

The stored grain insects that infest flour-mills are susceptible to low temperature and are quickly killed when the mills are thrown open and allowed to cool down to outside temperature during sub-zero weather. Opening the mills and stores to sub-zeor air temperature is practised in U.S.A. and Canada in regions with severe cold.

Cooling of grain in stores by drawing cold air through it is a recent development and has been described by Burges and Burrel (1964). The cooling is done by drawing the air from outside atmosphere through the grain. It is done through the installation of air ducts in the store, together with a number of fans according to the volume of grain stored. According to the authors, if temperature is reduced to 19°C *Oryzaephilus surinamensis* would not breed. Experiments with mobile refrigeration unit for drying and cooling damp grain have also been carried out (Herfod, 1962).

2. *Use of centrifugal force* : A special machine called 'Entoleter' is used to kill the insects. As described by Freeman and Turtle (1947) flour or grain is spouted to the machine in the normal feed flow of a mill and it is thrown by centrifugal force between two flat steel discs or plates that revolve on central shaft at 2,900 revolutions per minute. For whole wheat the speed should be 1,450 r.p.m. All stages of the store grain insects are killed by the impact of flour against revolving discs and posts of the machine. Entoleter is now a common equipment in flour-mills in U.S.A. and Britain.

3. *Use of radiation for disinfesting foodgrains* : The radiant energy includes sound waves, electric energy of various wave lengths such as radio frequency waves, microwaves and infra red, visible and ultraviolet rays. It also includes various forms of atomic energy (ionising radiation) such as X-ray, gamma rays, neutrons, and electrons.

The application of sound waves has not been found to be

structures are difficult to make airtight. Investigations of the relative suitability of concrete and aluminium bins for storing wheat have recently been carried out (Sarid, *et al.*, 1965). Two hexagonal cement concrete over head storage bins, each 18 ft. high and 8 ft. diameter with a storage capacity of 38 tons, were compared with aluminium bins 12 ft. and 14 ft. diameter with a capaciy of 28 tons. The changes in temperature of grain at the top and bottom levels in two types of structures showed in general a fairly close relation with the trend in ambient conditions. In both structures the top layer adjusted to the atmospheric temperatures more quickly, while the bottom layers were the slowest in this respect, particularly after the winter months. The middle layers showed an intermediate picture.

The temperature in cement bins was higher than the atmospheric temperature till January. Thereafter the grain temperature was lower except in top layers which had temperature near to that of atmosphere. In aluminium bins the difference between grain and atmospheric temperature was negligible till December but during the subsequent months it maintained lower temperatures until May. It seems that heat is dissipated more slowly in cement bins than in metal bins. The moisture content of grain in aluminium bins was slightly lower than the initial, practically throughout the storage period, whereas, in cement bins it was higher than the initial. At the end of storage period of one year the moisture content in aluminium bins was 11.4 per cent (initial 11.9 per cent) as compared to 12.7 per cent (initial 11.2 per cent) in the cement bins. While the differences in insect multiplication could not be made out the damage due to heating and fungi was higher in the cement bins than in the aluminium ones. The viability of grain decreased at a more rapid rate in cement bin than the aluminium.

The superiority of metal/aluminium bins over concrete bins may not be questionable but the cost of aluminium bin is perhaps prohibitive. If it is possible to make the following improvements in either concrete or metal bins, the grain is likely to store better :

1. Structure should be moisture/gas proof.
2. It should have a manhole of some non-conductor material.

practicable because of inefficiency of low frequency waves and difficulty of transmitting high frequency waves through the air. The use of Radio-frequency (R.F.) has also received considerable attention and it has been shown that this energy is effective in producing heat in the grain to a lethal level (130°F). However, no practical application of significance has been developed so far. Infra-red radiation also produces high temperature in relatively short period. Temperature to the level of 160°F with an exposure of 20 seconds have been found to be effective in drying the grain and controlling the insects (Krishna Murthy, 1965).

Ionising radiation (atomic energy) is also used to control insect populations in grains and other food products. The gamma rays from the waste products of nuclear reaction or from cobalt irradiator, are the most practical sources of irradiation of grains and food stuffs in preference to other forms of radiant energy. Studies on ionising radiation for insect control in grains and other products have been reviewed by Cornwell (1966) and Nelson (1967).

Further studies on the following lines are needed before the radiant energy finds a practical application :-

1. To evaluate the dosages necessary to sterilize the insects rather than aiming at killing them;
2. To prevent the development of unpleasant smell and deterioration of colours;
3. To prevent deterioration in quality of proteins;
4. To assess safety of irradiated food;
5. To check the presence or absence of any toxic substance in the irradiated material;
6. Quality of grain for seed purposes;
7. Quality of irradiated material over extended periods.

Research on these lines is in progress in various parts of the world. Since radiation is only a substitute for efficient fumigation method, the prevention of grain infestation from the outside sources during storage has to be achieved by other means reviewed in this article.

In conclusion it may be said that there is a great need and scope for the use of modern technology in solving the storage problems, keeping in view the basic principles applied for

the regulation of functional environment. This will mean less dependence on chemical control of storage pests, which is not at all a satisfactory method under peculiar conditions of storage in India.

In conclusion it may be said that there is a great scope for designing metal receptacles for use in rural areas. These bins, should be airtight, should not allow moisture obsorption or free diffusion of oxygen, should be practicable and easily manageable

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Chapter VII

Arid Zone Problems—Soil and Water Resources for Agriculture

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It is estimated that land surface exposed above the sea level is of the order of 15 billion hectares, and about one third of this has been classified, on the basis of climate and vegetation, as arid and semi-arid. These areas are not favoured with good rainfall and in fact large parts of them receive less than 25 cm. rain per year. Not only the scarcity, but also the variability of rainfall in these lands are the dominant elements in the complex of physical factors that set the stage upon which man ventures his livelihood. While the limits of arid lands are set by climatic conditions affecting the surplus and deficit of water for plant growth, the lands themselves differ greatly from place to place, because of the variety of water balance, and of the terrain. In addition, there exist profound differences in combinations of climate, land form, soil, vegetation and hydrology that are found within the limits of arid lands. The climatic patterns in these lands have, in some cases, influenced the patterns of population and livelihood. The problems cited in the following discussion, pertain to the environmental complex of arid and semi-arid areas of the Indian Sub-continent.

India has 169 million hectares of agricultural land out of a total of 326 million hectares of land surface. A large part of the cultivated area, 70 per cent of which is rainfed, falls into the arid or the semi-arid zones. This zone intrudes into

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all three broad gelological regions of India; the peninsular region, the Himalayas and region within ranges, and the Indo-Gangetic plains. Leaving aside the arid areas which are a part of Pakistan, the boundry of the arid zone starts from the eastern border of West Pakistan. This zone is bounded on the East by the Arvallis Hills, extending to 640 kilometres in length, and includes 1,12,700 square kilometres of Rajasthan desert, where average annual rainfall is less than 150 cm., often reaching as low as 50 mm.

The desert soils in Rajasthan are met with in the districts of Jaisalmer, Bikaner, Churu, Barmar, Jhunjhunu, part of Jalore, Ganganagar, Nagour and Sikar. This area is a vast sand plain interceptd by sand dunes, isolated hills and rockey outcrops. Other soil types included in this zone are grey brown soils, and grey brown soils of river basin in Rajasthan and pedocal sierozems of alluvial origin in Punjab and Haryana. Wadia (1953) thinks that sand in Rajasthan originated from long aridity and sand-drifting caused by the south-west monsoon winds. In the heart of sand-covered areas, the dune-free country of Barmar, Jaisalmer and Bikaner contains exposed marine deposits of Jurassic and Eocene periods.

The natural vegetation of this zone comprises xerophytes, halophytes, short grasses and shrubs. Three major ecological divisions may be recognized.

1. The area south and south-east of Aravallis Hills, which is not strictly in the desert.
2. The semi-arid, some 1,600 kilometres across, lying parallel to region (1), where a number of extreme xerophytes may be found.
3. The arid region in the extreme north and west of (1) where vegetation is very scanty.

The natural vegetation in these divisions is inter-mixed especially in the transitions between arid and semi-arid areas, and merges into lands of assured rainfall. The native vegetation consists mostly of *Cocculus* sp., *Zizyphus* sp., *Cappris aphylla*, *Calotropis procera*, *Acacia arabica*, *Salvadora oleaides*, *Prosopis spicigera*, *Butea frondosa*, *Sasola foetida*, *Citrullus coloynthis* and the like.

There are other areas of scanty rainfall also, particularly in the states of Gujarat, Mysore and other States, where agriculture depends upon the availability of rain water. The present discussion, however, is restricted to the areas of limited rainfall in the states of Rajasthan, Haryana and Punjab. This will help delineate the problems of an area having a more or less similar conditions. Even in this region the intensity of problems varies from place to place and sometimes a few problems are of a local nature.

Problems of dry farming : Arid areas essentially are lands of high risk and uncertainty. In such areas sparse resources of water, soil and vegetation are in delicate equilibrium. With the intervention of man, and under his occupation, the conditions are subject to both gross deterioration and to great improvement. It is well known that not only the extent of the area under cultivation, but also the intensity of dry farming depends upon the amount and distribution of rainfall. With the introduction of irrigation, dry farming areas have lately started squeezing. However, it will take many decades before suitable irrigation facilities are provided and still many areas will remain a desert. In Jodhpur and Jaipur from 25-50 per cent of the total area is under the plough. Irrigation facilities are few and the aridity puts a definite limit on the cultivable area. As most of the cultivation is associated with monsoon rainfall, a big portion of the land remains under current fallow. The middle north-eastern side of the arid zone, from Gujarat to Bikaner and from north-western Bahawalpur to the eastern limit of Ferozepur, is the area where the maximum percentage of the area is cultivated. More than half the total area is under the plough and in Ferozepur it is more than 75 per cent. This region receives comparatively more rainfall, has better soil and better-developed irrigation system.

Because of high summer temperatures, the arid region has the greatest evapo-transpiration demands and the least assured water supply. Many times the monsoon showers are flashy and unevenly distributed in the season. Conservation of this monsoon water is necessary not only for agricultural use but also for human consumption. Water entering into the soil as well as lost through flashy torrents must be conserved to derive the maximum benefits. Along

the foot hills of Arrvallis, particularly in Gurgaon and Ajmer districts there is available a unique system of conserving monsoon rain water for *rabi* crops. Rain water is stored in dams and is used for cultivation. Whatever percolates in the soil serves as a source of recharging the ground water and also in improving the quality of water. Sometimes the rainfall is in excess of the intake capacity of the soil and 20-30 per cent of the water received, may be lost as run off water, carrying along with 15-80 tons of soil per hectare. Contour bunding in these areas can help in the uniform absorption of water. Contour furrowing is another simple method which can be effectively used in areas of low rainfall. In arid farming the soil and organic mulches can be used to cut down evaporation losses. Having developed such devices the next most important factor is the selection of suitable cropping patterns. Naturally, the most successful crops will be those which combine drought-resistant and drought-escaping characteristics. The plants should have short growing season and low evapo-transpiration demands. This is a wide sphere of agriculture in which more researches are needed.

Problems of drifting sands and wind erosion : Drifting sands from Rajasthan have been encroaching upon the dry farming lands of Haryana, Punjab and other neighbouring States. This is mainly due to the characteristic desert climate but to a great extent also due to the disturbance caused in the environment by man. Such short sighted benefits as cutting the forests for wood or over grazing the lands might easily convert a semi-desert area into a real desert. The desert thus marches forward, winds cause soil erosion and the drifting sands choke crops, bushes and other vegetation. In the month of May, winds with a velocity of 20 miles an hour can shift large mounds of sand from one place to the other.

The problem is, therefore, not only to save the top soil from erosion but also to save other soils from getting deposit of unwanted cover. Over grazing in such soils must be stopped and steps should be taken to stabilize sand dunes. Proper soil conservation practices need to be followed to prevent soil erosion through the agency of wind. A suitable plant cover during the windy season is one remedy, but how to establish and sustain that cover is a problem which needs urgent attention. Suitable cultural practices must be evolved

and recommended for use in these areas, so that soil losses are minimized.

Irrigation for agriculture : Man's choice to use, develop or withdraw from arid lands is an intricate process in which he assesses the resources with which he has to deal with, applies the technology and skills at his command and drops the alternatives which seem uneconomic to him. In a country like India, with one of the highest proportion of land under plough in the world, it is not the question of withdrawing from any land anywhere, but is a matter of adjusting to different situations. As a national policy creation of vast potentials of irrigation is envisaged. The total surface water resources of the country have been estimated to be of the order of 167.3 million hectare metre (MHM), out which 55.4 MHM are classified as utilizable resources. Use of these resources by the end of second and third plan period is given below :

	End of second plan period (million hectare metre)	*End of third plan period (million hectare metre)*
Surface water resources utilized ..	14.7	18.45
Per cent of the utilizable potential ..	27	33

The above data shows that two-thirds of the utilizable water resources are still to be applied for irrigation. In addition to the 11.1 MHM of existing water, draft from wells, it has been estimated (Rao, 1969) that another 15.1 MHM of ground water is available for future exploitation. Using all these resources for irrigation, the present figures of 32 million hectares of irrigated area can be more than doubled.

Lest it becomes a very rosy picture, it must be mentioned that the distribution of this surface as well as ground water potential is very erratic. Gross area irrigated by surface water resources in Rajasthan, Haryana and Punjab is only 4.5 million hectares. Any further increase in irrigated area in Rajasthan will have to be met from sources other than

the Punjab rivers. The supply position of the Punjab rivers is shown below :

Canal system	Requirements of canals (MHM) at		
	Rupar	*Harike*	*Total*
1. Punjab canals	1.9252	0.4528	2.3780
2. Rajasthan canal	..	1.1416	1.1416

Total requirements of both the systems works out to 3.5196 million hectare metres. The live storage of Bhakra Dam is 0.7417 MHM and the requirement of water for irrigation from it is 1.7491 million hectare metres. Even after banking upon the catchment flows of rivers Sutlej, Beas and Ravi we have to depend upon the ground water resources. Total ground water recharge occurring through rainfall is about 35.2112 MHM, and another 5.4612 MHM occurs possibly through seepage from canals. Even after taking into consideration, the evapo-transpiration, sub-surface run off losses, and present annual draft a large part of this recharge can be used for irrigation. Against this all India picture the net ground water recharge available in the states of Haryana, Punjab and Rajasthan is only 1.0701 million hectare metres. A large part of this water is too saline for irrigation purposes. It is, therefore, evident that ground water resources in this region are limited.

Keeping in view the above facts the success of irrigated agriculture in these areas lies in the best and most efficient use of available water resources. Water, being a precious input, must be used with discretion. Very few soil surveys have been carried out in this region to determine the potentialities of irrigated farming. Water requirements of crops and the critical stages in their growth for water application need to be worked out. It would help in scheduling irrigation supplies from the headworks to the field level. Water conservation measures are helpful not only in saving irrigation water, but also in reducing the quantities of water infiltration to soil layers below the root zone. Efforts should be made to evenly distribute the draft on the surface and the sub-soil waters.

Water-logging : With canal irrigation system the hydro-

logical cycle is changed. The established balance between the rainfall and the natural surface and sub-surface drainage is upset. Physical obstruction to drainage of rain water, seepage from canal beds and the augmentation of evapo-transpiration demands through imported water result in increasing the proportion of water entering the sub-soil. It has been determined that in northern India average water loss by seepage from the canals and their branches is 17 per cent, from the distributaries is 8 per cent, and from the field supply system is 20 per cent. Assuming that 30 per cent of the water applied is beyond the root zone, then 112 cusecs out of a total of 182 find their way to the sub-soil. A very rough estimate on the probable magnitude of canal seepage in the country has been worked out. Calculations in parts of Punjab indicate that the magnitude of seepage from the canals is of the order of 115.37 hectare metres per kilometre of main canal per year.

Seepage and rain water have raised the water-table in Punjab, Haryana and Rajasthan. The average rate of water-rise from October to September in some canal zones is as under :

1.	Upper Bari Doab	..	17.6 cm. per year
2.	Sirhind canal	..	9.4 cm. per year
3.	Eastern canal	..	11.5 cm. per year
4.	Western Yamuna	..	6.7 cm. per year

The average rate of rise for these areas works out to 11.5 cm. per year. On the basis of this data, Mehta (1965) has worked out that 2,11,882 hectare metre of water will have to be pumped out annually to prevent the rise of watei table in different canal zones of the Punjab and Haryana. Similar observations have been made in the Chambal project under which water-supply was started in 1960. Within five years the area under high water-table was increased from 7,200 to 28,400 hectares.

The lining of main canals and their branches have substantially reduced seepage losses. Since small distributaries and field channels are still a significant source for water seepage, every irrigation program must accompany a requisite drainage program. For the surface and sub-surface drainage a great deal of spade work needs to be done. The direction

of ground water movement and soil stratography has to be investigated. Studies will have to be undertaken on the drainage requirements for a particular area, the practicability of drain construction, installation, the spacing, depth, maintenance, and cleaning of the drains.

Another feasible proposition has been the lowering of water table through shallow tube wells in strata that is permeable and has good water flow. The aquifers tapped should not be confined and those should have porous connections in high water table zone. Since this water is to be used for irrigation, the quality should be reasonably good. What adjustments are to be made when all these conditions are not met, should be worked out by researches. Where the quality of water from deep wells is poor, feasibility of recharging through good quality shallow aquifers may be investigated.

Problems of salinity and alkalinity : Salt problems are met with in all arid and semi-arid-areas of the world, especially where artificial irrigation is practised. An estimated one-third or more of the 120 million hectares of presently irrigated land face this menace. In India about 6 million hectares of land are affected by salinity and alkalinity and the soil condition is spreading to thousands of hectares of agricultural land every year. This problem is very acute in the three states under discussion, and with more areas being brought under irrigation, it is increasing every year in magnitude.

Salts are present at different places in the soil profiles. With rise in water table these salts move to surface layers along with. The evapo-transpiration in these areas being more than the effective precipitation, the rise of salts to the surface is accentuated. This problem is present in the deep water table areas also, where the circulation of water has increased through irrigation and the evaporating water leaves a load of salts at the surface. Consider a high watertable area where the salt concentration of sub-soil water is 400 ppm. If the surface evaporation in this area is one metre per year, and the salts are left in the top 30 cm. of the soil, the salt content of the soil will be raised from 0 to 1 per cent in 20 years. With the use of saline sub-soil water for irrigation salt content of the soil increases further. Unfortunately

saline water occurs in areas where there are inadequate facilities for irrigation and with its use thousands of hectares of productive soil has thus been rendered unfit for cultivation.

There is one redeeming feature that our river waters are one of the best in the world so far as quality is concerned. However, without striking a note of pessimism, a word of caution must be given for their use even. Let us take, for example, a very safe water of Indus system with an average salt content of 200 ppm. Assume that the average evapotranspiration demand for a double-cropped area in Rajasthan is 150 cm. Ignoring the small quantity of salts removed by the crops and assuming that there is no leaching, the salt content of the top 30 cm. of soil will be raised from 0 to 1 per cent within 24 years. It is, therefore, wrong to assume that the supply of good irrigation water to the needy areas is all that is needed. A careful study of the leaching requirements for different crops and drainage requirements of these areas will have to be carried out to find ways and means of preventing the onslaught of salinity and alkalinity problems.

Soil fertility and productivity : In addition to their having salinity, alkalinity, water-logging, soil erosion and associated problems, the arid soils are low in fertility. Because of scanty rainfall, the vegetation is very sparse and whatever is present is rapidly oxidized under high temperature conditions. The maintenance of soil fertility and the proper physical condition are all important for a successful agriculture. These soils generally have alkaline reaction, and contain $CaCO_3$ layers in profiles at varying depths. Being sandy in nature the soils hold very little water and nutrients. The phosphorus fixation and the low availability of micro-nutrients may be real problems in many cases. Problems of boron toxicity may also appear in certain areas. Very extensive studies will have to be carried out on the availability of these nutrients for the successful growing of crops and forests.

The arid zones have socio-economic and many other problems in the field of agriculture which have not been touched here. Upon the complex mosaic of physical environment rests the uncertainty of arid zone areas. It is by the scientific understanding of these problems that vast

desert areas can be made productive. Only then the growing food and fibre requirements of the nation can be met.

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Arid Zone Problems—Natural Vegetation

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The natural vegetation of India is governed by the complex of the envrionment such as climate, soils, geology, under-ground water, physiography and forest biota. Climatologists and plant ecologists have established the fact that climate depicts general picture of the natural vegetation and the minor details are completed by other factors. Considering Koppen's and Thornthwaite's climatic classifications and taking into account the edaphic, physiographic, and biotic factors, Champion (1936) has made a detailed classification of the natural vegetation of India which is still considered the best so far.

In the plains and the plateau regions of India, rainfall is the major determinent of vegetation types. This is because of the fact that rainfall variations are more significant than the variations in other elements of climate. In the mountais temperature varies rapidly with abrupt rise in elevation. Thus, unlike plain areas, the influence of temperature on the character of the vegetation in the mountains is as significant as that of rainfall. Keeping in view, the physiography, India falls into two broad divisions of natural vegetation : mountainous India, where the natural vegetation is sub-tropical, temperate and alpine; extra mountainous India, where the natural vegetation is tropical, varying from ever-green rain forests to thorny scrubs. There are no sharp boundaries between different types of vegetation. The tropical, the subtropical and arid zone vegetations generally merge one into the other. So, along with vegetation of the

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semi-arid and arid zones, a summarized account of the vegetation of the adjoining areas is also discussed.

I. Mountainous India : 1. *Western Himalayas* : Western Himalayas extend from Kashmir to Kumaon and receive 100 to 200 cm. of annual rainfall. In the lower reaches of these mountains, up to a height of 1,000 metres, the natural vegetation is tropical and sub-tropical, mainly consisting of deciduous trees like sal and bamboo. In between 1,000 and 3,500 metres is the temperate zone where oak is the most important tree. Oaks, either alone or mixed with conifers constitute an important feature of the vegetation of Himalayas. Beyond 3,500 metres and up to the timber line is the alpine vegetation consisting of the forests of silver fir, junipers, pines, birches and rhododendrons.

2. *Eastern Himalayas* : This is the humid region of the Himalayas and lies to the east of Sikkam. Vertical zoning of the vegetation is similar to that of western Himalayas. The difference in the vegetation is because of greater amount of monsoon rainfall, higher temperatures and humidity in the summer, and less snowfall in the winter. Many plants of this zone at the lower elevations are evergreen and the under-growth is thicker as compared to the western Himalayas.

Apart from the useful trees, there are excellent grasses which grow in the Himalayas at various elevations. The wide open stretches of grasslands, in between the timber and snow lines, constitute the best pastures of India. In lower Himalayas and in the Siwalik Hills, *Themeda* and *Arundinella* grasses are quite important.

3. *Western Ghats* : Western Ghats are not so lofty as the Himalayas and there is no snowfall in these mountains. Because of smaller areas occupied by these hills, the sub-tropical vegetation is found in restricted localities at heights between 1,000 and 1,500 metres. Upward from 1,500 meters to the top of the hills is the temperate zone where the average temperature ranges between 7°C and 24°C in a year. Due to very strong winds in this zone the trees are not so high and the growth is very dense, especially where phy-siography and climate are favourable. There is much under-growth of the temperate and tropical vegetations.

II. Extra Mountainous India : Ignoring the minor details, extra-mountainous India is divided into four major zones on the basis of rainfall. A comparison of rainfall distribution map with that of main vegetation types indicates a close relationship between the two.

1. *Wet zone :* In this zone the annual amount of rainfall is more than 200 cm. and the variability of rainfall is less than 15 per cent. One block of this zone covers Assam and north-east Bengal and the other, Malabar coast and lower slopes of the Western Ghats. The vegetation is typical of the rain-forest. Evergreen vegetation is found in the plains and the lower slopes of mountains, below a height of 1,200 metres, where the rainfall is more than 250 cm. However, where the rainfall is less than 250 cm., the vegetation is semi-evergreen represented by a number of species. The evergreen forests are very dense and the trees are very high, more than 60 metres in hight. Because of the deep shade of the trees, the under-growth is often absent and the floor is relatively bare. The butteressed trunks are common and epiphytes are highly developed in these forests.

2. *Humid zone :* In the humid zone of India, the annual amount of rainfall is 100 cm. to 200 cm. North-eastern part of the India Penninsula falls in this zone. The natural vegetation there is tropical deciduous forests, commonly referred to as monsoon forests (Spate 1954). Wherever the rainfall is more than 150 cm., the forest type is moist deciduous. The growth of the trees is very dense and the height ranges between 25 and 40 meters. The under-growth is also thick and is often evergreen. The number of species growing is quite large but the most common are sal, teak, sandal wood, coconut and bamboo (Puri 1960). On the other hand where the rainfall is 100 to 150 cm., the forests are dry deciduous and are not very dense. The height of the trees ranges betwee 15 and 25 metres. In addition to sal and teak, the other important trees are *sisso*, *hurra* and *mahua*. During the rainy season there is a luxuriant growth of grasses which can be cut and stored as hay.

3. *Semi-arid zone :* In this zone the annual of rainfall is 50 cm. to 100 cm. and the variability of rainfall is 35 to 50 per cent. The north-western, the central, and most of the

peninsular India falls in this zone. The typical vegetation varies from dry deciduous to thorny forests. Th trees are generally of stunted growth and are leafless for a part of the long dry season. The herbs and the grasses are dessicated during the hot dry summer and many of the trees are typical xerophytes, adapted for dry conditions, and having devices for conserving moisture. The commonest trees are the leafless *Capparis decidua*, *Salvadora oleoides*, *Acacia arabica*, *Prosopis spicigera* and several species of *Tamarix*. On the saline soils grow *Salyadora persica* and *Butea monosperma*. There are various species of herbs which store up a large quantity of moisture in the leaves and also there are rosette plants with tough penetrating rootstocks. In central India there is a large variety of trees but *Boswellia serrata* and *Surculia urens* are the two conspicuous species of great economic value, the former for match boxes, match sticks and paper pulp, and the latter for gum. *Dendroclanus strictus* is the common species of bamboo used for the manufacture of paper pulp. Further south, in the rain shadow of Western Ghats, the vegetation is of dry thorny type. However, where rainfall is comparatively more, it forms an intermediate stage between the monsoon and the xerophytic forests.

The semi-arid zone is the important livestock breeding region of India because of the availability of many nutritious grasses. In the northern parts of this zone *Dichanthium annulatum* and *Cenchrux caliaris* are the most economic and dominant grasses (Whyte 1964). In south, where the rainfall is more than 50 cm., *Heteropogan contortus* and *Alpuda varia* are important. *Aristida funiculata* is found where the fainfall is less than 50 cm. In the Kutch area there are vast stretches of the Banni grasslands which are important assets of the region because the cattle population depends entirely on these grasses. As the tract is saline, it supports nothing else.

Throughout the semi-arid parts of India, however, uncontrolled grazing in the grasslands has greatly contributed to the dessication of fertile areas. In order to save the area from further encroachment of desert conditions and to maintain the fertility of the land an improvement of the vegetation cover of the semi-arid areas is very essential. This can be achieved by checking the over-grazing and by planting more trees of high economic value. For example

in the sub-Siwalik region large scale plantation of khair (*Acacia catechu*) and *sissoo* can replace the uneconomical vegetation. Extensive stretches of these trees have already been planted along the banks of rivers, streams, canals and along the roads and railway lines. Eucalyptus is an important tree which can be planted successfully over large areas. Another tree which can be planted in this zone is *Prosopis juliflora*. The greatest advantage of this tree is that it can grow on very poor soils and is most suitable for the reclamation of Usar and dessicated soils.

There is a vast scope of growing a number of grass species of very high economic value. *Saccharum munja* is a useful grass for checking wind erosion and for paper making. The others which hold a good promise are *Themeda cymbaria* and *Eulaliosias binata*. Both the grasses make good pastures and can be used for paper making.

4. *Arid zone :* The aird zone covers south-western Punjab and Haryana, whole of Rajasthan and estern parts of Gujarat. The annual amount of rainfall is less than 50 cm., and the variability of the rainfall is over 50 per cent. In the centre of the desert Marusthali, the amount of rainfall is less than 15 cm. This is the hottest region of India where the maximum temperature of 50°C has been recorded (Tewari 1968). The winds are constantly from west and south-west for a greater part of the year and have a dessicating effects, except in July and August when they are charged with moisture. Topographically it is a dry undulating plain of rolling sand-dunes of various dimensions. Marginal dunes are relatively stable whereas inland they are constantly on the move. At places compact rock is exposed. The physiography of north-western India is such that no perennial river crosses this arid part. Similarly, no sub-soil water drains in from the adjoining regions. The percolation of rainfall is the only source of sub-soil water in the region. Since the amount of rainfall is very small, the water supply to the sub-soil is highly limited. The only favourable sites of sub-soil water are along the Aravalli hills and the low lands and depressions where water tends to drain during the rainy season. Because of inland drainage the soils of the depressions have high accumulation of salts. The soils are also deficient in organic matter and have a poor water-holding capacity.

Under these environmental conditions, the vegetation of the region is extremely xerophytic in nature. Over vast stretches it is very poor and there are vast barren tracts of sand-dunes. Plants exhibit various adaptations to the low supply of water. Some plants show a high degree of resistance to high temperature and dessication. The two most important are *Capparis aphylla* and *Euphorbin royalea*. These plants have no leaves, their functions being performed by green twigs. *Prosopis spicigera* is another important tree of the desert. The tree once established can withstand long periods of extreme drought. It is one of the most important and useful plants for the people of the arid region. Thus vegetation of the typical desert can be divided into two groups : plants which depend solely upon rains and plants which solely depend upon sub-soil water (Sarup 1953). The plants which depend entirely on rain water are mainly annuals and die at the end of the rainy season. The plants which depend upon sub-soil water are perennials. Many of the perennials, however, resemble the annuals because the above-ground portions of the plants dry up completely every year except when it is exceptionally moist. Some of these plants have high medicinal value. In saline areas few plants grow because of the physiological drought created by the high concentration of salts. *Tamarix diocia* is the only important plant which grows in the dry and saline water courses and on the banks of saline depressions.

There are few grasses in the typical arid areas of Rajasthan. *Cenchrus catharticus* is found all over the arid region. The other one, *Elionurus hirsutus*, grows where the rainfall is less than 20 cm. This grass can be planted and is quite tender in nature.

Much of the arid zone of India is without any vegetation cover and is mainly under the shifting sands. These vast reserves of unused land are the potential regions of forestry, crop production and livestock grazing The exploitation can, however, start with a sustained and systematic process of land reclamation and conservation. To start the process is to check the wind erosion by creating shelter belts which reduce wind erosion. There are a number of local xerophytic trees, scrubs and grasses which can combine to form most suitable shelter belts. These belts when errected in right directions will bring the sand-dunes to stability. The recla-

mation of sand-dunes can be carried out by planting grasses, etc. Thousands of acres of sand-dunes have been reclaimed in Israel in this manner. There are a number of trees and grasses which have been tried in India and have grown successfully in sand-dunes (Rao, 1962). Extensive areas of sand-dunes have also been reclaimed in U.S.S.R. with bitumen emulsion. Similarly, large number of sand-dunes have been reclaimed in Tripolitania by planting different types of xerophytic vegetation. Moisture balance can be improved in the arid zone by introducing more canals, exploiting under-ground water, and making artificial rain. Except for the Rajasthan Canal, there seems at the present no possibility of taking any other big canal to the interior of the desert. Under such conditions, ground water is the only promise. In the desert areas of U.S.A., Africa, Isreal and Australia, the geologic and geophysical surveys have brought fruitful results in improving the water conditions of those areas. These investigations are highly encouraging for improving the water conditions in the Indian desert. However, the provision of irrigation alone will not improve the productivity of the desert. Many desert soils bring excellent results under irrigation, but the majority are converted into saline and alkaline soils after a few years of applying irrigation water. Vast tracts of soils of arid zone have excessive salts where irrigation will bring no fruitful results. So steps must be taken to remove the excessive salts from the soil where irrigation potentialities exist. Successful results have already been demonstrated in Isarael (Ravikovitch 1953).

Once there is an improvement of the environments by way of checking wind erosion, reclamation of sand-dunes and by improving soil moisture conditions, the arid zone of India offers vast potentialities for crop, forage, and timber production. Large tracts of land can be brought under native food crops and grasses. Further, there lies a great scope for bringing and establishing many plants and grasses of very high economic value from similar locations of other countries. Australia has achieved a great success in introducing many pasture plants from other countries and these grasses are now of great importance to that country. Likewise, Israel has introduced many useful desert plants from countries with similar climatic condition (Dickson 1953). Results obtained from similar trials in the Central Arid Zone

Research Institute, Jodhpur are most encouraging for establishing the new plants in our desert.

The forest and agriculture development plans of the arid zone of India should be based on the integrated results of the findings of the scientists of various skills and professions.

1. Different regions should be recognised on the basis of the similarities of problems and potentialities. These regions should be delineated after a detailed survey of the geology, hydrology, soils and climate of the entire arid zone.
2. The development of the most promising areas should be initiated first and should start with checking wind erosion, reclaiming sand-dunes and tapping the under-ground or the canal water.
3. Those varieties of the trees and grasses should be introduced which have been tried and recommended for such environments.
4. In areas brought under cultivation, the recommended agronomic practices such as strip cropping stubble mulch farming, crop rotation and mixed cropping should be followed.

In the research programs for the development of arid zone, the aspects which need greater attention are :

1. The analysis of the mechanism of rain formation so that artificial rain could be made available on economical and large scale in regions with no promise of canal and tube-well irrigation.
2. The analysis of the mechanism by which some plants can survive very high temperatures and extreme aridity. If this mechanism is intencified many more valuable plants can be bred and collected which will be tolerent to high temperature and extreme aridity.
3. To evolve such varieties of crop plants and grasses which can grow in soils containing excessive salts or which can be grown by using brackish water for irrigation.

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Arid Zone Problems—Natural Fauna

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The deserts are considered to be one of the principal biotic regions of the earth and are characterized by the absence of forests or thick vegetation, the scarcity of food and water, and the extremes of climate. Their bioconesis includes distinctive vegetation and animal life that have undergone specialized adaptation suited to the rigorous conditions of the environment prevalent. Now here is the dependence of animal life on vegetation more evident than in the deserts; for the plants provide the animals with their essential food, water and shelter. The battle against drought is first won by the plants, and where plants exist there are animals. The advantage that animals have over plants is their mobility. Plants are fixed to the ground and have no choice but either to adjust themselves to their immediate environment, or to die. But the mobility of an animal enables it to reach a more favourable environment. The important fact to note here is that both plants and animals have managed to resist the hostile elements of the desert climate by developing various mechanisms of adaptation. These adaptations may be broadly classified as ecological, behavioural, functional, structural and genetic.

Desert flora : It is estimated that not more than one fifth of the vast desert flats is covered with vegetation (Kirmiz, 1962). These desert plants have sclerophyllous adaptations to retard transpiration and survive long periods of drought. Foliage becomes greatly reduced, even absent altogether,

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during long periods; stems contain the chlorophyll necessary to carry on photosynthesis. Cell walls are thick, highly ligneous, and have thick cuticles. The cell sap increases in osmotic pressure and hydrophilous colloids. Cacti store considerable water in their stems as a reserve for use when there is no water in the soil. Biotic succession is not conspicuous in the desert because of the low rate of reactions by organisms upon the habitat (Shreve, 1942). When the vegetation is disturbed it is usually replaced directly by the same type without interventing serol stages (Muller, 1940).

According to Buxton (1955), who studied desert flora in relation to animals, the three most important groups of plants are as follows :

(1) The annuals, whose seeds survive a dry period of months or years and whose stems, leaves and flowers are not structurally modified to resist dryness. They appear after rainfall and are short lived.
(2) Plants which grow leaves and stems, and flower after rainfall. The lower parts exist throughout the year beneath the ground as a bulb, corm, tuber or fleshy root for storing food.
(3) Plants which have made adequate structual adjustments in order to reduce loss of water from the surface or store it in the body of the plant, or both.

Hence we may conclude that the desert flora have found various ways of adjusting their vital processes to the severe conditions of the environment and that in the course of their long struggle they have developed specialized features distinctive of the desert biotic region to which they belong.

Desert fauna : For the study of desert animal life the two principal factors that need consideration are the periodical climatic changes and the ability of animals to move from place to place. A limited number of forms are able to survive the unfavourable environment of deserts and to become adjusted to it. Since vegetation is very sparse, only a small amount of animal life can subsist. Among other animals, there exist antelopes, gazelles, small carnivora, jackals and foxes, jerboas, small rodents, reptiles, birds,

numerous insects, etc. Many of the animals are runners, jumpers or burrowers. Also their hair are of a light colour resembling the colour of the desert soil. Aridity being the dominant factor in the desert, the principal problem of animals is the acquisition of sufficient water for their metabolism. According to Dekeyser and Derivot (1959), among the land animals of Sahara there are those which drink regularly—those which drink irregularly, those which are satisfied with the preformed water in their food, and those which do not drink.

The rhythm of desert life is to a great extent dictated by the daily and seasonal cycles of the sun and the irregular cycles of rainfall. The severity of climatic stress on the vital processes of organisms is closely associated with these cycles. This is why desert animals everywhere have found generally similar ways of solving their problems of adjustment.

Most desert animals are nocturnal; they pass the day inactively, hiding in their places of shelter or sleeping in their own or in other animals' burrows. They find protection in the shade of every possible refuge, such as stones, niches, holes, crevices, caves and bushes. Desert animals which spend the day dormant are active at night in search of food and prey. The carnivora devour the herbivora, the mighty and crafty prey on the small and weak. It is the small world of rodents that provides the main food of birds, reptiles and mammals. The herbivora try to satisfy their hunger and quench their thirst by whatever vegetation and grain they are able to find.

Animal adjustments : The two most critical environment factors in the desert are the high temperatures especially during mid-day, and the lack of water. Animals tend to avoid extremes of high temperature rather than to tolerate them for any length of time. They do this in various ways. The small mammals, snakes and even insects are largely nocturnal. Birds are active chiefly in the cooler hours of early morning and evening and tend to remain quiet and concealed during the middle of the day. Nearly all animals spend their time above ground in the shade cast by the scattered shrubs or rocks, and it is here that they have their burrows or nests. The pack rat makes a pile of bits and pieces of plants, creeps under it and so protects him-

self. Many animals make their nests inside plants where it is shady and cool. For example, the elf owl (*Micropallas whitneyi*),which lives in arid parts of Arizona, nests exclusively in holes made by two wood-peckers, *Centurus uropygialis* and *Colaptes chrysoides mearnsi*, in stems of giant cactus, *Cereus giganteus*. The range of the elf owl is limited by the distribution of these two biotic elements of its environment. So if there are no wood-peckers, it is hard for elf owls to live in the desert.

Birds' nests occur most frequently on the East and North-East side of plants, where they are shed from the hot afternoon sun. Even the grasshoppers come to rest in bushes to avoid the hot ground surface as much as possible. Grasshopper species confined to hot sandy areas have long slender legs that hold their bodies away from the ground. Many mammals, reptiles and insects (ants, crickets) burrow deeply into the ground and thereby avoid the surface heat, for example, the burrow of kangaroo rats penetrate 50-65 cm. below the surface near Tucson, Arizona (Summer, 1925).

Many desert animals are adapted to go a long time without drinking water. The kangaroo rats of the Sonoran desert never drink water and their food, dry seeds, contains only a very small amount of moisture. Another small source is the water that is formed when their tissues break down carbohydrates in the food they eat. Predators may find enough water in the blood of their prey; and herbivorous animals can find water by eating tissues of succulent plants. Among the higher animals, camel has unique specialisation of water conservation. It has a thick wad of hair, has the capacity to store water in stomach, and can also utilize the water of metabolism from the fat stored in its hump. The remarkable character of suspended animation under dessicated conditions is common among the snails. They resume activity as soon as water becomes available. The urine of mammals is more highly concentrated than in non-desert species, and feces egested in a dry condition, the excess water having been re-absorbed in the large intestine. Water is conserved in the bodies of birds, insects and many desert reptiles by kidney wastes excreted as solid uric acid salts rather than as urine.

Many animals live in the crevices between rocks or

burrow among them. Rock dwelling animals are called petrocoles and include snails, spiders, other arthropods including ants and various small lizards and mammals. Petrocole lizards are characteristically flat, as is an east African land turtle (*Testudo tornieri*) that also lives among rocks.

The running, jumping and burrowing vertebrates play an important role in the desert. Many desert animals develop great speed and endurance in their movements, which are more to their advantage as there are fewer hiding places. Because of their speed, such animals are able to escape their enemies, to traverse daily great distances to water, and to migrate from summer drought to winter drought. The lizards are for the most part slender, very active and agile. Among the birds the larks and courses (*Cursorius*) are important.

Jumping mice and jerboas are the best representatives of the jumping animals. Such jumping mammals are characterised by an enormous development of the hind limbs and tail and an atrophy of the forelimbs. It is difficult to understand what advantage this affords the smaller forms, but it is believed that their zigzag, ricocheting movements aid them in escaping predators.

Burrowing forms are at home in sand desert. Rodents are the most numerous burrowing mammals. They dwell side by side in suitable places in the open country in such numbers that the ground is undermined over wide stretches. Reptiles are especially abundant and are able to dig themselves into the sand very quickly. The species of *Phrynocephalus* in Asia and *Pharynosoma* in the American South-West produce horizontal movements with their flat bodies and disappear rapidly into the sand. The rostrum is particularly well developed and extends beyond the mouth in many snakes, and lizards of the desert; they burrow through the sand by means of lateral movements of the head.

Of all the groups of animals adapted to desert life insects need special mention. They have developed such characters which not only save them from excessive evaporation but also make them most suited to hot and dry atmospheric conditions. They have well developed integument. The

chitinous exoskeleton is almost fused segmentally in such insects as the tenebrionids, curculionids, carabids and cicindelids. In them evaporation of body fluids is prevented. A number of bombiliids and asilids are highly pilose and are thus saved from intense heat by the reflective nature of hairs and scales. Numerous orthoptera and a number of beetles in the arid zone are wingless. This morphological character saves them from strong winds. Elongated legs enable the insects to break contact with the hot sand surface and at the same time allow them to walk swifty on sifting sands. There are still others that find it safer to dig into the sand. They have fussorial legs as in case of some grasshoppers like *Austroicetes cruciata* in Australian deserts.

Desert animals in all parts of the world resemble in colour and pattern of their environment. There are inexplicable exceptions, equally world-wide, in which a striking black coloration is developed. Because of the lack of cover, colour adaptation to the substratum has been shown to have biotic importance for desert animals. Thus, the pale yellow or reddish colour of the desert is seen in many animals. Numerous orthoptera, most of the snakes and lizards, many birds, and mammals of numerous genera have the same colouration. A resting grasshopper, a lark, or a desert courser, sitting quietly, is unusually difficult to distinguish. As these colours harmonize with the desert environment, they are thus essentially cryptic in function, providing them protection against enemies. In other animals, the colours are also most permanent and these therefore aid in disclosing the distasteful nature of the species concerned to their predators.

Plant-animal relationships : An outstanding example of plant and animal relationship in arid zones is that of the weed opuntia and its insect parasite *Cactoblastis*. The moth *Cactoblastis*—which occurs naturally feeding on *Opuntia* in America, was introduced into Australia in 1925 at a time when the prickly pear was at its peak in that country. The moth multiplied at fast rate, quickly destroying the prickly pear over large areas around the point of liberation. But soon a point was reached, when there was very little prickly pear left for countless millions of moths. By chance a few of the moths succeeded in finding odd plants here and there on which to lay egg[illegible] end result, which still persists,

is that *Opuntia* is relatively scarce over vast areas but it is doomed to destruction because *Cactoblastis* is able to increase rapidly on it.

Another example of plant and animal inter-relation is that of grasshopper, *Austroicetes cruciata*. There is a complex relationship between the insect life cycle, vegetation and climate of that area. In the egg stage the grasshopper has an obligate diapause and thus there is only one generation a year. Emergence coincides with the growth of vegetation and generally, there is plenty of food for the nymphs to develop. In summer, a large number of adults die of starvation, because there is intense heat, the grass wilts and the food supply is depleted; but still a good number successfully lay eggs. For the rest of the summer, the eggs remain in diapause and have a remarkable capacity to withstand severe drought. Deaths occur in varying proportions of the population if there is excessive desication of the eggs during summer. Normally this is prevented by the occasional shower of rain. If there is drought just when the nymphs are ready to hatch during spring, they become trapped under the compact surface of the soil. In years of scant vegetation, the grasshoppers congregate at the favourable situations where birds prey upon them intensively.

As for the dreaded locust there are no well-defined outbreak areas of the world from where swarms of *Schistocerca gregaria* would originate out of the resident population. Fresh swarming may arise either from a carryover of the earlier swarms or from the concentration of scattered solitary locusts. A single concentrated oviposition from one swarm may give 20 times as many hatchings as the parents. As a matter of strategy, therefore, it is of great practical value to restrict the breeding areas as far as possible, by cultivation, and by the use of human factor in controlling hoppers. The outstanding example is that of locust control strategy in the State of Punjab. The districts that lie north of the Rajasthan Sind desert are just as favourable for the multiplication of locust and the formation of swarms. But he control operations carried out there, particularly at the hopper stage were so well-organized in the recent years that no swarms were allowed to be formed. It was possible through well distributed village populations in the Punjab and Haryana States.

The animal and plant life in desert areas can be enriched by various ways. Animals being directly or indirectly dependent on plants for food and shelter, their impact on vegetation should be such that growth of vegetation is encouraged, erosion is reduced to the minimum and top soil is protected. Whatever little moisture is gained can be conserved and even agriculture can be practised by long range rotations. There are, in fact, vast areas in Australia, having less than 10" rainfall, where pastures are raised during good years and all sheep are pulled out during dry years.

Man can have comparatively greater control over the deterimental factors. Erosion and rodents or other enemies of vegetation deserve special attention. As animals burrow and bring large quantities of loose soil to ground surface exposure, the likelihood of wind erosion destruction is greatly increased. Wind erosion can be prevented by long stretches of wind-breaks and aforestation. The existing trees and shrubs can be gainfully propagated and better species can be introduced from other deserts of the world. A selection of the numerous species of gum trees found in Australia may prove useful in Rajasthan.

Animal destroyers of vegetation like the rodents, can be discouraged by the introduction of carnivorous predators. It is likely that the races of desert cat present in Tumeristan may do well here. Likewise other useful and beneficial animals can be introduced. After making a survey of the wild flowers of various regions of Rajasthan it may be considered worthwhile introducing the Sahara race of *Apis mellifera* which is supposed to be the best race of honey-bees. The workers of this race are known to fly up to a distance of five miles and are thus very efficient collectors of nectar and pollen.

The species of plant or animal that are selected for introduction must essentially be useful. The benefit expected can be ensured only if their ecology and physiology is known. The possible interspecific relationship should be studied thoroughly before introduction, lest they become terrible accidents like the notorious introduction of *Opuntia* and the European rabbit in Australia.

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Chapter VIII

Extension Education Through Agricultural Universities

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One of the new features introduced in India through the Agricultural Universities is the integrated approach to resident instruction, research and extension education, whereby all the teachers serving in any one of these constituencies have to devote one-third time for either of the other branches. This keeps teaching and research problem oriented, and the extension workers are kept aware of the new research findings. The Directorate of Extension Education of the Punjab Agricultural University has successfully endeavoured during the last six years to serve the interests and needs of the farming community of the State through its multidirectional activities by keeping these objectives in mind. It was possible through the three wings: the Farm Advisory Service; the Junior Staff School; and Agricultural Information Service. With this set up the Directorate of Extension Education has been able to project the image of the University not only to the farmers of this state but also of the rest of the country, and this part of the world.

I. Farm Advisory Service : The Farm Advisory Service is an organic link between the University research departments and the farmers with the following staff :

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(A) University Subject Matter Specialists in the subjects of : (i) Agronomy, (ii) Plant Protection, (iii) Horticulture, (iv) Soil Science, and (v) Extension Education.

(B) District Level Subject Matter Specialists in the subjects of : (i) Agronomy, (ii) Plant Protection, (iii) Horticulture, (iv) Soils Science, and (v) Farm Management.

These subject matter specialists work in close collaboration with the State Department of Agriculture. In fact, at the district level, they are under the local administrative control of the District Agricultural Officers. The activities of the Farm Advisory Service include :

1. *District level farmers' training camps :* Three-day camps are held twice a year before the beginning of *rabi* and *kharif* seasons to equip the farmers with the latest advances in scientific knowledge for maximising agricultural production. These are then followed by one or two-day camps at block and village levels.

2. *Demonstration centres :* There are thirty demonstration centres in each district in which entire holding of the cultivator is taken as a unit for the purpose of demonstrating superiority of modern techniques. Detailed accounts are maintained with respect to inputs and output under thorough supervision of all the Subject Matter Specialists. In addition to these there are two to six demonstration centres under each discipline.

3. *Demonstration trials :* These are laid out on the recommendations of various University experts and include simple field trials such as, varietal, manurial and of plant protection measures.

4. *National demonstration plots :* These are laid out to increase the intensity of cropping along with maximum production of grains, on the advice of the Central Government.

5. *Field days* are one-day shows held according to the needs of every discipline, where some extraordinary performance is to be exhibited.

6. (a) *Agricultural bulletins :* Monthly Agricultural

Bulletins are prepared jointly by all the Subject Matter Specialists at the District Headquarters under the supervision of the District Agricultural Officer, outlining various Agricultural operations to be performed by the farmers during the month.

(b) *Special bulletins* on new topics which are considered necessary for specific situations are also issued by the Subject Matter Specialists.

7. *Package practices :* To enable all the extension workers to speak with one voice about the agricultural recommendations, a three-days agricultural Officer's Workshop, comprising all the Gazetted officers of the three states, is held twice a year before the *kharif* and *rabi* sowings and package recommendations are finalized. There is thus a diffusion of knowledge amongst the Extension and Research workers and they arrive at considered decisions. The package practices are then published for general use.

8. *Special campaigns*, like pohli eradication, soil and water testing week, killing of rats and fruit propagation campaigns are organised by different disciplines at the proper time and place.

9. *Shows and exhibitions* are arranged on special occasions—religious and social fairs, or those arranged by the Community Development Department.

10. *Research projects :* Small and simple projects like insect pest population studies, rejuvenation of orchards, and agronomic trials are given to the Subject Matter Specialists for operational research.

11. *New seeds :* Seeds of new high-yielding varieties of crops are distributed among progressive farmers for early trials.

II. Training programmes : The Department of Extension Education of the College of Agriculture serves as one of the most vital links in disseminating and communicating useful and practical knowledge in science and technology to the farmers. This is done by organising various types of training courses in the Junior Staff School. The present

programme of training is carried out by the staff provided in various schemes such as :

(i) Junior staff school.
(ii) Practical education to young farmers.
(iii) Specialised training to selected farmers.
(iv) Training to agriculture sub-inspectors and sons of farmers.
(v) Farmers training and education in high-yielding varieties.
(v8) Agriculture Teachers' Training Class.
(vii) Training in Minor Irrigation for Extension workers.

The following activities are being undertaken in order to make direct impact and contribution in increasing the professional efficiency and competency of serving personnel, as well as members of the farming community :

(i) Holding of refresher courses and inservice training courses for the field staff of all the categories connected directly or indirectly wih the programme of agricultural improvement in the State.
(ii) Training the sons of farmers as a pre-service course.
(iii) Holding of courses in specialised subjects like, horticulture, vegetables, farm machinery, etc.
(iv) Holding of courses of short duration for the farmers, interested in all aspects of arable farming.
(v) Holding of courses of longer duration for Young Farmers, and imparting intensive practical education in agriculture.
(vi) Providing information and advice to farmers through correspondence and visits.
(vii) Providing resource-persons at the farmers training courses organised by the field staff.
(viii) Organising *Kisan Melas* to acquaint agriculturists with the latest findings in the field of agriculture.
(ix) Organising School Students Fair for attracting brilliant students to the profession of agriculture.

An idea of the number of training courses and the number of participants can be had from the yearly progress.

S. No.	Year		Total no. of courses: Held	Total no. of courses: Progressive	Total No. of trainees	Progressive total
1	1963-64	..	40	40	1,071	1,071
2	1964-65	..	64	84	1,529	2,600
3	1965-66	..	64	148	2,445	5,045
4	1966-67	..	65	211	3,720	8,765

III. Agricultural Information Service : The Agricultural Information Service aims at disseminating agricultural information acquired and developed through the research programmes of the Punjab Agricultural University to the widest possible areas of farming community and in bringing back, in the shape of postal enquiries, the problems of the farmers, which are transmitted to the respective departments for suitable replies. In keeping with the objectives, the information service assumes threefold responsibility : producing and distributing printed literature; utilising audio-visual media, such as exhibitions, films and radio services for the benefit of the farming community; and of feeding the press with the news items, press releases, photographs and news stories.

Under this programme is also published a quarterly Journal of Research in which are printed papers of the University Scientists. A popular journal "Progressive Farming" provides practical information to the farmers. '*Unnat Kheti*' and '*Changi Kheti*' are two Hindi and Punjabi versions of Progressive Farming which carry about the same material as is published in the English monthly "Progressive Farming". The Department also publishes a monthly "News Bulletin" for reporting various developments in the University, including changes in staff and other building activities.

The Department also puts out farm bulletins on various crops, animal husbandry and on special features allied to agriculture. Besides, some research bulletins on special research projects undertaken by the University scientists are also published. It is the responsibility of the department

to publish the Annual Report, a comprehensive handbook for extension workers and other books and bulletins needed by the University Administration or Constituent Colleges.

Agricultural exhibitions are arranged at various fairs and farmers' meets in the State. Publicity is undertaken through press releases, All-India Radio, and by printing hand-outs.

The visitors who come to see the University are taken around by the staff and put in touch with various specialists of the University.

Importance of Field Training in Agricultural Extension

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Concept of practical training : There can be no two opinions on the fact that practical training is a very important pre-requisite for sound agricultural education at the school, college and university level. It has been observed that agricultural students suffer a great set-back due to the lack of practical biased education. It is, therefore, necessary to consider the exact *nature* and *scope* of such practical training. Agricultural graduates find their scope of employment in teaching, research, extension and industry. Practical training in this connection has to be related to different opportunities in which graduates in agriculture will receive their future employment.

Need for creating new outlook in practical training : In what direction does the movement seek to bring about a change of outlook ? The first direction in which we must change the outlook of the rural masses is in regards to two evils (i) under-employment that grips the country (ii) subsistance agriculture, i.e. the land does not produce a fraction of what it can produce if existing scientific knowledge is applied. Intensive agriculture by bringing modern scientific methods to the doors of the farmers would bring about greater production and fuller employment and along with it wider opportunities for subsidiary and cottage industries.

Agriculture has been rapidly changing with the times and now the centuries old sickle has been replaced by modern

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mechanical tools. Therefore, the practical training must also keep pace with the new needs of a fast changing agriculture in the country. Today is the age of machines, our agriculture has to be revolutionized and new horizons of practical training have to be found with the following ends in mind :

1. Specialization in farming has expanded in various technical directions and it has to be further intensified. This will require the graduates in agriculture to advance their knowledge in the specialized fields of agriculture such as fruit farming, poultry farming and fish farming, etc.

2. In view of mechanization and specialization of various agricultural enterprises, the students have to learn new skills about modern equipments, both bullock and machine drawn.

3. The use of high-yielding varieties of paddy, dwarf wheats, hybrid maize and *bajra* etc., have made a major break-through in our agricultural production and the farming pattern is also becoming more intensive with the increased use of fertilizers and irrigation. In view of this technological progress the student-community at large will have to learn and keep pace with modern methods of training in the areas of efficient soil and water management and crop production techniques.

4. The role of agricultural economics in relation to input out-put relationship has become very much rationalised; and with the modern production tools, labour efficiency and management of the farm, agriculture has to be treated as a business. Practical training, therefore, has to include the principles and practices of business management in agriculture for efficient and economic returns.

5. The importance of using effective plant protection measures for the control of insect-pests and diseases and the extensive use of herbicides for the control of weeds has been realized by the progressive farmers and, therefore, the practical training of students has to be oriented and organised on these new lines.

Scope of practical training : The students in agriculture in various colleges and universities have limited

practicals during class hours since any practical on an agricultural aspect cannot be covered well in a two-hour assignment. But class-room teaching can become more effective and better assimilated if the same is well-performed in practicals.

Some of the Agricultural Colleges and Agricultural Universities have made a great headway in improving the practical training on very sound lines. Intensive practical training for about six weeks is also in predominant practice in some Agricultural Institutions but this also has a disadvantage in that the practical training is not covered throughout the year in various seasons. Students studying for B.Sc. (Agri.) degree should be given basic practical training throughout the year so that instructions given in the class-rooms are put to practice. Occasionally, students of the same elective group should be sent to various places like fruit and vegetable farms, poultry and general crop farms so as to well acquaint them with the practical aspects of agronomic principles.

Gap between knowledge and practice : It is well recognised that agricultural research is proceeding on sound and practical lines in India. The research workers have evolved high-yielding varieties which have revolutionized our agricultural production. The various ways of controlling different pests and diseases have also been discovered. By experiments in the fields, the optimum time for sowing, the seed-rate to be adopted for different crops, the best time for manuring, the economic dose of fertilizers for maximum production and economic water requirements of various crops have been investigated but all those have not been practised by progressive cultivators. What does this show ? It exposes the fact that research has been mostly confined to the laboratories remaining aloof from the practical problems which face the cultivators and that the results do not reach the Farming Community. Thus even the personnel in touch with scientific developments often display ignorance as to what our research stations are doing. Thus there is a wide gap between the experimental stations and the cultivators' fields.

This gap can only be filled up by 'Agricultural Extension' which is teaching outside the research laboratories and class-

rooms. It is a two-way-channel : it bring scientific information to the rural people and it also takes the problems of the people to the scientific institutions for solution.

Modern methods of extension : The success of any extension method depends upon its *simplicity*, *economy* and *ease* with which it can be demonstrated and on its educative and instructive value in changing the attitude of the student community and the cultivators. In U.S.A., a detailed study has been made of various teaching methods, many of which have been tried under Indian conditions. Extension workers should study what are the ways to bring the largest return with the minimum cost. Any method or technique to be employed depends upon the object in view, the programme in hand, the availability of the material, the cost involved and its convincing value for those who cannot read and write much.

Students in the practical class or farmers in the fields will make changes on understanding the 'why' and 'how' of the technique. The greater the number of 'whys' and 'hows' given,the greater are the number of changes made. This has been verified in a study which was made in U.S.A., where it was found that if people were shown 'how' a change should be made in 5 to 6 ways, seven out of eight families changed their ways.

To achieve this, in the past, we have adopted a large number of methods, such as to give printed literature, and to arrange demonstrations in the field, lectures, exhibitions, etc. Some of the methods used in extension service are given below :

1. *Demonstrations* : Dr. S. A. Knap, has stated 'What a man hears, he may doubt, what he sees, he may possibly doubt, but what he does himself, he cannot doubt". Thus demonstration is one of the best methods for breaking the natural resistance of people to change.

(a) *Method demonstration* : It is a way to show 'how to do' a new practice —how the fertilizer is mixed or how sorghum seed is to be mixed with sulphur to prevent disease. The success of demonstration will depend on the active interest or participation of local leaders.

(b) *Result demonstration :* It is the presentation of results of of a practice at a meeting or of a fertilizer trial where farmers can actually see the results. Effectiveness of such demonstration will be enhanced, if charts or other devices are used for explaining what was done and how the results were obtained. Practical demonstration on actual farms arranged by people, who know both agricultural science and practice will, therefore, accomplish a great deal in raising the production, even where farmers cannot read and write.

2. *Individual and group meetings :* For solving the farmer's personal problem, it is necessary to contact an individual for discussion. Such contacts offer him an opportunity to ventilate his views. Consulting individuals should be conducted in a pleasant and satisfying but business-like and time-saving manner.

However, if it is intended to give wide publicity to the results of demonstration plots, a big meeting should be organised. Group meeting should be used for presenting method and result demonstration, conducting discussion, stimulating organised efforts andfor giving useful materials. Ensminger has stressed the importance of such meetings and he said, "By mobilising neighbourhood and community groups, we can assist local people to think straight, get the desired facts, formulate well founded judgements, turn gossip into education and to convert fear into faith and confidence."

3. *Agricultural shows :* These shows are organised by agricultural departments and research institutions. Advantage is taken of social and religious groups during meals and festivals in rural areas where cultivators get an opportunity to see better varieties of seeds, improved implements, manures and fertilizers. Group discussions and demonstrations of such exhibits, will serve a useful purpose to change the primitive ideas of the farmers for the use of effective, cheap and improved appliances for better production.

4. *Audio-visual aids :* J. E. McClintock found that average attendance at meetings where it is known that pictures are to be shown, has been much better than in many other types of meetings. In many villages of India, it is also

observed that people attend in great numbers when Ram-Lila, puppet shows or some other entertaining programmes are announced for such meetings. All classes of people in the community including young and old, rich and poor are attracted there. So, under Indian conditions, audio-visual aids have a bright future as a teaching tool if much expenditure is not involved.

5. *Information service* : Newspapers are an effective media for spreading information. The information to be released to farmers should, therefore, be blended into news stories. The art of news writing and, adaptation to what the papers want leads to effective newspaper publicity. Advantage may be taken of *newspapers, newsletters,* pamphlets which are issued by departments of agriculture and research stations for use by the cultivators. Village evenings are generally spent in gossip but when useful publications are made available free of cost, they are read with great interest.

The relative importance of all these methods should be studied for maximum benefits with least costs. The success of any method will depend on its simplicity, economy and the ease with which it can be demonstrated and its instructive and educative value in convincing the cultivators. Fundamentally, *three* conditions contribute to the success of these methods :

(i) Efficacy of recommended practice under the reconditions prevailing.

(ii) The capability of the extension worker to creates confidence among the cultivators.

(iii) Proper and timely publicity so that the maximum number of people participate in these programmes.

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Extension Education in Veterinary Science

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Although there is firm recognition of the importance of extension work in agriculture, the intensity of such recognition seems to be very much lower in veterinary science and animal husbandry. As such, two basic questions crop up : does the knowledge from the fields of veterinary science and animal husbandry need to be conveyed to the farmer; if so, who is to convey this knowledge ? A positive reply to these questions necessitates the delineation and description of those problems.

A variety of information from research in veterinary science and animal husbandry needs to be communicated to the farmers. This may be considered under the following headings :

Veterinary services : How to recognize disease. When and what indigenous treatment should be given. When to consult the veterinarian. How to control and prevent contagious diseases. The importance of disease control. Benefits of evolving a disease-free herd. How to report outbreaks. What first-aid a farmer can give to his animals in various surgical, gynaecological and medicinal affectations?

Animal feeding : What fodder calendar should be followed? What feed should be given to different animals? Time and method of feeding. The importance and method of clean watering. Availability and utility of prepared and proprietary feeds. Grazing and pasture development, etc.

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Animal breeding : Recognition and utilization of estrous in different species of animals. Number of services required for pregnancy. Pre-and post-partum care. Selection, maintenance and use of bulls. Improvement of animal production through selection and breeding. What should be reared and bred ? When and how to get calves castrated. How to reduce age of maturity. Enhancing total productive period through breeding, etc.

Animal management and hygiene : Maintenance and importance of hygienic environment for animals. Construction of well-ventilated and senitary byres and sheds. How should the daily routine of animal management proceed. Importance and methods of maintaining cleanliness of animals. Domestication of highly strung animals, etc.

In such a programme of extension education, as outlined above, it is essential that a simultaneous and parallel programme of research in the parent subject should continue. This would ensure a smooth and continuous flow of information from the veterinary institutes to the farmers. For this feed back, it is essential that farmers' problems in these areas be brought to the notice and comprehension of the research workers. Extension workers, therefore, shall have to keep constantly in touch with farmers' problems in the area of veterinary science. Some guidelines in this direction are presented below :

Study of existing practices : As anamenasis and diagnosis are the pre-requisites for the rational treatment, the problems in their real shape and form may not be spotted out systematically unless the current practices are studied and analysed. For example, we need to know at what age the farmers get a calf castrated, and why; what feeds do the farmers feed their animals and in what proportion ? What treatments they give to the ailing animals, etc. etc.

Discussion with the villagers and experts : To determine the utility and technical validity of these practices a thorough discussion with both parties is demanded. If possible, the experts and the villagers may be given opportunities to discuss such problems frankly.

Evaluation of community and individual resources : Fre-

quently, animal husbandry problems exist because of lack or absence of inputs. It is, therefore, necessary to evaluate the financial and material resources available with the farmers, so that recommendations may be made within the limitations imposed.

With this two-way flow of information established, it should be possible to align research and extension work in the field of veterinary science. It may be pointed out that this is not all. Side by side, research in extension education is also to go on. This should be focused mainly on the problems encountered (administrative and adoption problems for the most part) in the implementation of such procedures, with a view to evolving improved methods of performing extension work. This requires a steady availability of research workers in extension education trained in the veterinary and behavioural sciences in a balanced fashion.

In recognition of the importance of the scope of extension education in veterinary science, Punjab Agricultural University was the first in India to start with the production of masters of veterinary extension. A similar effort is now being made by the other agricultural universities in India, but this is not the be-all and end-all of the pioneer steps taken by this university. It is feared that if the services of these personal are not utilized for the benefit of veterinary science, the effort will go to waste.

Agricultural Production-Yearly Targets

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Agriculture plays a very important role in the economy of a country. In India it contributes about 50 per cent of the national income. Over 70 per cent of the population depends upon agriculture and for the improvement in their living standards, it is necessary that agricultural productivity is raised appreciably.

Erstwhile Punjab State was deficit in the production of foodgrains at the time of partition, but with strenuous efforts the deficit was turned into a surplus. In the first two Plans, Agricultural Production in the Punjab registered an increase of 76.5 per cent compared to the All-India figure of 46.4 per cent.

During the period 1950-51 to 1960-61, the production of foodgrains increased by about 76 per cent, that of cotton by 260 per cent, that of sugarcane by 225 per cent and that of oilseeds by 137 per cent. The agricultural production advanced at the average linear rate of about 4 per cent per annum during the year, 1949-50 to 1961-62 with the trienium ending 1951-52 as its base for the country as a whole. The area under crops increased at the rate of about 2 per cent per annum while the productivity advanced by 1.5 per cent per annum. In the State of Punjab the annual linear rate of growth of agricultural production during the year, 1952-53 to 1961-62 was 5.62 per cent. The increase in agricultural production due to increase in area under crops was 2.56 per cent and the net agricultural productivity increased by 2.55 per cent. The annual linear increase due to increase in acreage during the corresponding period was 2.3 per

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cent while the productivity increased by 1.84 per cent. For non-foodgrains crops, the increase due to added acreage was 4.27 per cent and the productivity increased by 3.17 per cent, indicating the trend of cultivators using intensive means of cultivation for cash crops and also for utilizing relatively more of the inputs for increasing agricultural productivity of the non-foodgrain crops.

The State of Punjab has faced a number of changes, in as much as in the year 1947, a part of it went to Pakistan. In the year 1957 the States of Pepsu and Punjab were merged and again for the third time in the year 1966 the Punjab State was re-organized on linguistic basis between Punjab and Haryana.

The present State of Punjab has a population of 1.1 crores of which 77 per cent is rural. The total area of the State is about 5 million hectares out of which 3.86 million hectares is cultivated. The total cropped area is 5.1 million hectares giving the cropping intensity of 131 per cent. The net irrigated area is 2.1 million hectares out of which 0.88 million hectares is irrigated by wells and tube-wells, etc. About 91 per cent of the total cultivable area has already been brought under plough. Any increase in agricultural production, therefore, can be brought about only by increasing productivity and multiple cropping. Agricultural production is closely linked with the assured water supply conditions. This relationship between assured irrigation and agricultural production is interesting in as much as that such of the foodgrain and other agricultural crops, which were receiving assured irrigation, there has been a steady increase in production, whereas in crops which were mostly rainfed, there have been fluctuations depending upon weather conditions.

The targets for agricultural production during the year 1966-67 (for erstwhile Punjab State) were 71.7 lakh tons for foodgrains, 12.1 lakh tons for sugarcane (*gur*), 3.3 lakh tons for oilseeds and 12.6 lakh bales for cotton. No separate targets were fixed for re-organized State of Punjab. The following targets of agricultural production have been proposed for the year 1967-68 :

(In lakh tons/bales)

Commodity		Base level for fourth plan	Additional production	Total production
Foodgrains	..	39.5	3.2	43.9
Oilseeds	..	2.0	0.2	2.4
Sugarcane	..	5.1	0.35	5.8
Cotton	..	*8.4*	*1.00*	*9.0*

The major programmes of agricultural development are discussed below :

(a) *Minor irrigation :* A sum of Rs. 1.51 crores was provided for advancing loans to the cultivators for sinking of percolation wells, pumping sets and tube-wells during 1966-67. This programme is likely to bring 38,000 additional acres under irrigation.

It is hoped that by the end of the current year about 10,000 tube-wells will be energized as against 11,000 during the year 1966-67.

The State Government has given a very high priority to this programme during the year 1967-68. It has earmarked Rs. 3 crores on various minor irrigation schemes including Rs. 2.6 crores for advancing loans to the cultivators for the installation of pumping sets, tube-wells and percolation wells. This programme is likely to result in bringing an additional area of about 63,000 acres under irrigation.

Loans for pumping sets and tube-wells in the un-electrified areas will be given.

(b) *Soil conservation :* During the year 1966-67, about 31,000 acres are expected to be covered under soil conservation and soil water use management programmes.

The soil conservation programme particularly the soil and water use management programme is being given high priority during the year 1967-68. It is proposed to spend about Rs. 75 lakhs on the various programmes and over an estimated area of about 42,000 acres. The water con-

servation work is intimately linked with the minor irrigation work. It is estimated that under Punjab soil conditions any where from 20 to 40 per cent water is lost by the time it reaches the place of its utilization, which obviously means that for every hundred rupees spent the cultivator is taking benefit of sixty rupees only. In view of this and under this programme it is proposed to build *pucca* channels to carry the water. At some places underground water channels are also being laid out, not only to save water, but also to save land which otherwise would come under the water channels.

(c) *Seeds and fertilizers :* It was planned to distribute about 2.25 lakh tons of fertilizers during the year 1966-67. Because of the paucity of supplies and difficulties in the availability of credit to the cultivators, the total consumption will be about 2 lakh tons.

Increase in the use of chemical fertilizers is essential for immediate increase in agricultural production. It is proposed to distribute about 7.60 lakh tons of various fertilizers (in terms of CAN and superphosphate) during the year 1967-68. In order to enable the cultivators to apply recommended doses of fertilizers, arrangements have been made to supply fertilizers on credit. Cooperative credit will be further strengthened with a view to enable cultivators, who are members of cooperatives, to get requisite quantities of fertilizers on credit.

As the provision of good quality seed forms the very basis of scientific agriculture, the State Government is planning to affect substantial improvements in the supply of quality seeds.

(d) *High-yielding varieties programme :* Fortunately some high-yielding varieties of wheat, maize, *bajra* and paddy are now available which offer a great potential for speedy increase in agricultural production. During the year 1966-67, about 45,000 acres have been covered under hybrid maize, 11,000 acres under Taichung Native-1 variety of paddy, 1,400 acres under hybrid *bajra* and about 1.5 lakh acres under dwarf varieties of wheat. In order to accelerate the pace of coverage under Mexican wheats, the erstwhile State arranged to import about 22,000 quintals of wheat seed from Mexico and distributed the same for multiplication.

This programme was followed in 82 Blocks of the State including 10 Blocks under the Intensive Agricultural District Programme, Ludhiana.

The High-Yielding Varieties Programme is the pride programme of the country for obtaining a very rapid increase in agricultural production. This programme will be implemented in 87 selected Blocks including 10 Blocks of district Ludhiana. These Blocks have been selected mainly on the basis of the availability of assured irrigation.

It has been suggested during the current year to put 1.25 lakh acres under Hybrid *Bajra*, 75,000 acres under Hybrid Maize, 50,000 acres under Taichung Native-I, and 10 lakh acres under Mexican wheats.

(e) *Package programme for the development of long staple cotton :* Cotton is an important cash crop of the State covering an area of 4.8 lakh hectares, which is about 6 per cent of the total area in the country. The yield of lint in the State is about 300 kg. per hectare as compared to about 119 kg. per hectare for the country as a whole. This State contributes about 15 per cent of the total cotton production in the country. The important cotton development programmes undertaken during the year 1966-67, were supply of pure seed, use of fertilizers and control of pests of cotton. About three lakh acres were sprayed from the ground and air during the year 1966-67. The insecticides required were supplied at 50 per cent subsidized rates while the spraying charges from the air were subsidized to the extent of 66 per cent.

During the year 1967-68, it is proposed to cover the entire American Cotton area in the State under the package programme and increase the production of cotton by one lakh bales. The pest control programme will be further strengthened by spraying 7 lakh acres both from the air and the ground. Concession of 50 per cent subsidy on pesticides and 66 per cent subsidiy on the aerial spraying charges will be continued during the year. The most conspicuous programme of the current year is aerial spraying; 13,000 acres were sprayed last year. It has been suggested that eventually the entire area under American Cotton will be sprayed by aerial means.

(f) *Development of sugarcane :* Sugarcane is an important cash crop and covers an area of about 3.40 lakh acres in the State. Depending upon the price of cane and *gur*, the area under this crop fluctuates from year to year. The cane development work is mainly carried out within a 10 mile radius of the sugar-mills. During the year 1966-67, the production targets of sugarcane were fixed at 54.5 lakh tons and 25.10 lakh tons for the State as a whole and for the cane development zone, respectively. It was hoped that the average yield of sugarcane would rise from 16 tons and 20.9 tons per acre in the State and development zones, respectively. However, due to failure of monsoons and severe frost during 1966-67, it was not possible to achieve these targets.

During the year 1967-68 the total production is planned to be increased to 58.00 lakh tons (5.8 lakh tons of *gur*). It is proposed to supply two lakh maunds good quality disease free seed from the seed nurseries maintained in cultivators' fields. Stress will be laid on the control of pests of sugarcane through seed treatment, soil treatment, spraying of the crop and mechanical removal of the affected plants etc., etc. The insecticides required for this purpoes will be supplied on 50 per cent subsidized rates.

(g) *Plant protection :* It is expected that an area of about 60 lakh acres of crops will be covered for the control of pests and diseases as against the target of 50 lakh acres fixed for the year 1966-67. This included an area of 3 lakh acres sprayed both from ground and air against various pests of cotton this year. It is estimated that Rs. 22 lakhs will be utilized for giving subsidy on insecticides.

With more emphasis on intensive cultivation programme the incidence of insect-pests of various crops is likely to increase and unless efforts are made to minimize the losses caused by the insects, our efforts to increase production may not bring the desired results. It is, therefore, proposed to further strengthen the plant protection organization in the State during the year 1967-68. Pesticides worth Rs. 1 crore are proposed to be purchased for supply to the cultivators at 50 per cent rates. Pest control equipment will also be supplied on 50 per cent subsidized price.

(h) *Improved agricultural implements* : Improved agricultural implements were subsidized and a sum of Rs. 3.31 lakhs is expected to be utilized for this purpose during 1966-67. Besides, a sum of Rs. 6 lakhs is expected to be advanced as loans for purchasing tractors.

During the year 1967-68 it is proposed to popularize and to supply some selected implements like seed-*cum*-fertilizer drill and bullock driven disc harrows at subsidized rates. As in the past, loans for the purchase of agricultural machinery will also be made available.

(i) *Development of fruits and vegetables* : Financial and technical assistance was provided to the cultivators to plant more orchards as well as to maintain old ones. A sum of Rs. 1.6 lakh is expected to be advanced as loans for planting orchards. It is estimated that about 1,500 acres will be planted under various fruits during the year 1966-67. For supplying pedigree plant material two progeny orchards-*cum*-nurseries have been started during the current year.

For the extension of grape cultivation, about Rs. 4 lakhs are expected to be advanced to the cultivators. About 200 acres of new grape orchards are expected to be set up during this year.

During the year 1967-68, new orchards will be started over an area of 1,500 acres. Technical advice and financial assistance to the extent of Rs. 2 lakhs as loans will be provided for this purpose. Similarly, Rs. 3 lakhs will be advanced as loans for putting new grape orchards. The production and distribution of disease free potato seed will receive particular attention. It is proposed to establish a new potato seed farm for the production of seed of newly-evolved varieties of potatoes for further distribution and multiplication through the registered potato growers.

Punjab has been and will continue to enjoy, for all time to come, a very important place among other States of the country as the granary of India. It may not be far wrong to say that this State alone can wipe out to a considerable extent the deficit of foodgrains in this country. The cultivators of Punjab have earned a world-wide reputation for their hard work and labour. It may be mentioned that the

farming of today is very much different from that of 30-40 years back. It can now be favourably compared with industrial production whereby production is intimately connected with the resources of the industrialists. The increased production of agriculture, therefore, has a direct bearing on the inputs and dependent facilities which the State Government can afford to the farmers.

The Department of Agriculture, has undertaken a very extensive programme for increasing agricultural production and it is felt that it will be possible for this State to achieve all the commitments, in the matter of agricultural production.

Green Revolution in the Ludhiana District

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Granted that Sukhatme's (1965) projections on the year in which increase in food production must catch up with the rising population so as to avoid famine, are correct; granted that the modern science and technology has shown that it is possible to increase food production at the desired rate; granted that in India a machinery has been created through Agricultural Universities and State Departments for utilising the new techniques of Agricultural production, then production of food and fibre must be increased to prove the saying that "The proof of the puddling lies in its eating".

The proof must come through the demonstration of new skills and techniques and increased agricultural production. One such experiment was carried out at the instance of the Ford Foundation in seven States to start with and subsequently expanded to 11 States of India. In each one of the States, one district was selected for the Intensive Agricultural District Programme and Ludhiana was selected in the Punjab. Considering the availability of good sub-soil water, good soil, comparatively less water-logged areas and less alkalinity and salinity problems, and good farm size, Ludhiana was considered potentially the most promising and the best district in the State of the Punjab. Also the location of the Agricultural College at Ludhiana was an important factor. The success achieved through this

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programme is an example which is worthwhile giving in the end of this book.

Before mentioning the achievements, it will be pertinent to give a little background as to how this idea developed. The history of Indian agriculture in the field of education, research and extension is inevitably connected with the various reports of the Famine Commissions, starting in the latter half of the last century. After every major famine, a Commission was appointed, a report was submitted and the Government of India under the British Rule implemented some of the recommendations of the Commission. Thus, Departments of Agriculture were established for development work, Statistical Units were started to estimate and forecast the crop yields, Agricultural Colleges and various Research Institutes were established where to train graduates and scientists, and the latest in the series of these efforts, is the establishment of Agricultural Universities in various states of India on the pattern of Land Grant Universities in U.S.A.

In the past various development programmes have been followed in different provinces or States of India from time to time and policies have been changing according to the whims and wisdom of the administrators. Throughout the country, by and large, the most common pattern up to the end of Second World War has been that the State Director of Agriculture had his own Deputy Directors appointed in each of the Divisions of Civil Administration, along with an extra Assistant Director of Agriculture (later on named as District Agricultural Officer) in each of the Districts. At the Tehsil Headquarters, an Agricultural Assistant of the same status as Revenue Assistant was appointed. With the help of the retinue of his staff, the Mukadam (redesignated as Agricultural Sub-Inspector) and fieldmen, the Agricultural Assistant maintained Demonstration Farms, helped in agriculture and cattle fairs and demonstrated improved agricultural practices to the farmers and also facilitated in the supply of seeds and fertilizers. All these technical persons were under the administrative control of the Director of Agriculture but at the District level, they were also responsible to the Deputy Commissioner or the Collector for the development work.

After independence in 1947, the Government of India

constituted a Planning Commission which was entrusted with the job of laying down policies for planned economy. Although Agriculture remained a state subject always, yet the Central Government influenced the policies a great deal by granting financial aids for various schemes. Coinciding with the First Five-Year Plan (1951-52 to 1955-56), the idea of Community Development Blocks in rural areas through National Extension Service was also implemented under the directions of Mr. S. K. Dey. The N.E.S. Block was the administrative unit headed by a Block Development Officer who was required to coordinate and supervise the work of the Departments of Agriculture, Animal Husbandry, Panchayats, Cooperatives, Rural Industries and subsequently also Public Health, primarily Family Planning. One Block was so organised as to benefit about one lac population which in Punjab lived in approximately 80 to 100 villages. For the technical assistance of the Block Development Officer the staff provided at the headquarters was : one Agricultural Inspector (same as Agricultural Assistant), one Inspector in Cooperatives, one in Industries; Social Education and Panchayat Officer; Veterinary Assistant Surgeon; one Inspector in Public Health. In addition, there were approximately, 10 Gram Sevaks, each one of them having a jurisdiction over 8-10 villages; about five Gram Sevakas, responsible to the B.D.O. through a Lady Social Education Organiser. Technical recommendations of the various Inspectors appointed at the Headquarters were implemented through the advice given by the Gram Sevakas to the women and by the Gram Sevaks to the farmers and artisans. Both the Gram Sevakas and the Gram Sevaks had the minimum qualifications of Matriculation followed by about two years' multi-purpose training in Extension Training Centres. It is not difficult to visualise that too much was expected of the last man in the ladder and the various targets fixed by the State Government were ultimately to be achieved by this poor jack-of-all-trades who was master of none. On top of this all, the Gram Sevaks were put on such odd, and sometimes emergent tasks, as collection of hearth tax, funds for Red Cross Society helping in the drive for the purchase of National Savings Certificates, collection of funds for famine and flood relief, etc., etc. Thus, the Gram Sevak who was supposed to be the strongest link in the chain of administration, ended by becoming the weakest link. Contrary to the expectations for increased agricultural production and rise in education

level of the rural people, most of the attention was paid to meeting the physical targets as communicated to them through papers. There is no doubt that in a large number of villages such works were undertaken, as pavement of streets, construction of culverts, a few buildings meant to serve as Community Centres, approach roads, drains, etc. The much desired self-sufficiency in food remained to be achieved.

On hearing voices from the lobbies, the Government of India gradually started believing that there might still be some lacunae in the administrative set up which could be a limiting factor in achieving the desired results. With the help of Ford Foundation, an Agricultural Production Team was instituted in 1959. After studying the development machinery and administrative set-up in different States, the Team suggested a new programme in which it was desired to improve contacts with farmers and to provide ample agricultural inputs as well as credit.

The basic machinery suggested for agricultural development was essentially the same, only it was to be reorganised and new outlook was to be given. The main objective was "to increase income of the cultivator and his family". To achieve the maximum results with the available resources, the programme suggested that "All the factors, likely to contribute significantly to rapid increase in food production, would be combined into one integrated package programme". The main philosophy of this programme was to demonstrate in Pilot Districts the most effective ways of increasing farm production with the cooperative efforts of the Centre, the State , the District, the Block, the Village and the individual cultivator. It was emphasised that for obtaining any tangible results the supply of inputs along with desired credit and the speedy disposal of the farm produced at remunerative prices were the essential pre-requisites for the success of this programme.

The most important feature, though not the most outstanding, was to provide definite improved recommendations based on modern knowledge of technology, whether gained from within the country or from outside. It was, therefore, desired that services of senior specialists in various subjects such as Soil Science, Agronomy, Farm Management, Plant Protection, Horticulture, Farm Machinery, Animal Husbandry,

Cooperatives, Evaluation and Information, should be available in the I.A.D.P. District. Senior Agricultural Officer at least of rank of the Deputy Director of Agriculture, would be responsible for the execution of various schemes of agriculture development. He would work under the direct control of the Deputy Commissioner and Development Commissioner of the State Government. The Agricultural Colleges and Agricultural Universities were naturally to play a key role in finalising the various recommendations in respective fields of specialisation.

In the I.A.D.P. District of Ludhiana, Gurmail Singh Sandhu was appointed the first Pilot Project Officer and he worked in this capacity from September 1960 to December 1965. This charge remained with B. S. Atwal for a few months and then in May, 1966 Pritam Singh Hoshiarpuri was entrusted with this important job.

This district is situated approximately at the latitude of 30° 56'N and longitude 75° 52'E and the annual rainfall is 70.09 centimetres. Much of the rainfall is during the months of July, August and September. Therefore, adequate sources of irrigation are essential for growing high-yielding varieties by the application of fertilizers. In area, Ludhiana covers approximately 3,427 sq. kilometres, which makes approximately 9.87 lac acres. Out of this area approximately 7.74 lac acres were under cultivation during the year 1967-68. Since more than one crop are raised from some land, the total cropping area comes to 10.35 acres which gives, approximately 133% of intensity of cropping. Only 71% of the cropped area is under irrigation and quite a large acreage is still under *Barani* crops. It is interesting to note that 83% of the water supply is through minor irrigation works and remaining is through the canal system. Whereas it is possible to grow only one crop in the unirrigated area at present, more than one crop can be grown provided farms have independent means of irrigation.

As compared to other districts of Punjab, density of population in Ludhiana may be considered of the average type, there being 298 persons per sq. kilometre. The total population of the district is about 11 lacs out of which approximately 70% or 8 lacs live in villages. According to the census of India (1961) figures, not more than 1.4 lacs actually

cultivate the soil. The entire rural population comprising approximately 45,000 farming families live in 988 villages. According to these figures, one farmer cultivates approximately 5.5 acres.

In this district, the major crops grown are wheat, groundnut, maize, rice, sugarcane, cotton, gram and *bajra*. Near the cities, fodders, berseem, maize and vegetables are grown intensively. In order to determine the mark of improved administration, increased supplies and services and greater farm credit, on the total agricultural production, it is considered desirable to compare the increase in yield of major crops over the base year 1960-61, when the I.A.D.P. programme was initiated (Table 1).

The yield of wheat increased from 16.4 maunds per acre in 1960-61 to 20.4 maunds in 1965-66 and to 34.1 maunds in 1967-68. The seed of Mexican varieties Lerma Rojo and Sanora 64 was given to the farmers in the year 1965-66 for the first time. By the year 1967-68 about 95% of the irrigated area under this crop was brought under high-yielding varieties. It may, therfore, be noted that the introduction of high-yielding varieties coincided with increase in the number of tube-wells, and increase in fertilisers consumption, resulting in a phenomenal increase in the yield of wheat per acre.

Likewise the production of maize which is a *kharif* crop has also increased phenomenally from 15.52 maunds per acre for the year 1960-61 to 26.79 maunds per acre in 1965-66 and 26.11 maunds per acre for the year 1967-69. Other crops like, *Bajra*, sugarcane and cotton also followed more or less the same trends during this period. The yield of groundnut which is an important cash crop of the district increased from 10.13 maunds per acre in 1960-61 to 16.19 maunds in 1965-66 but fell to 13.33 maunds per acre in 1967-68. There has been a three fold increase in acreage since 1960-61 and it is indicated that some marginal land brought under this crop resulted in an overall decrease in yield per acre in the recent years.

Now the question arises as to what are the cogent reasons for such great increases in the yield of crops. Increase in the use of fertilizers and enhanced irrigation facilities particularly tube-wells, introduction of the high-yielding varieties, parti-

cularly of wheat and maize, better use of farm machinery, particularly the tractors seem to be the primary factors. Another measure of the increased agricultural inputs is the enhancement of the credit facilities available to the farmers. The amount of loan advanced by the cooperative societies in the year 1961-62 was 174.38 lacs which was increased to 475.45 lacs during the year 1967-68 (Anonymous, 1968). The loans given by the cooperative societies are generally in kind and such inputs as fertilizers, pesticides and farm machinery, etc. are made available to the farmers on easy terms.

TABLE 1

Agricultural Development in Ludhiana District (Punjab-India)

Particulars		1960-61	1965-66	1967-68
(*A*) *Average yield per acre* (in maunds) :				
Wheat	...	16.14	20.40	34.11
Maize	...	15.52	26.79	27.11
Rice	..	16.63	8.50	14.50
Bajra	..	2.50	10.12	5.44
Groundnut	..	10.13	16.19	13.33
Cotton (American)	..	2.56	3.39	3.57
Sugarcane (*gur*)	..	42.61	42.84	44.50
Potato	..	194.23	190.36	132.64
Barley	..	11.64	12.7	13.97
Gram	..	11.64	7.9	8.41
(*B*) *Total Agricultural Production* (in thousands tons) :				
Foodgrains	..	229.0	430.0	704.0
Pulses	..	54.6	0.8	17.37
Oilseeds	..	25.5	79.5	91.4
Other crops				
Cotton (in thousand bales)		35.0	52.9	36.2
Potato	..	3.9	14.2	1.2
Sugarcane	..	38.0	62.0	44.0

Particulars	1960-61	1965-66	1967-68
(*C*) *Agricultural Inputs*:			
Fertilizer consumption (tons)	5,629	5,115	84,664
Fertilizer consumption per cultivated acre (kg.) ..	8	66.1	110
Pesticides :			
Liquid (litres) ..	15	3,040	13,143
Dusts and wettable powders (kg.)	7,571	35,434	84,931
(*D*) *Agricultural Credit* (Rs. in lacs) :			
(i) Medium and short term loans by the Co-operative Societies	174.38 (1961-62)	369.24	475.45
(ii) Loans and subsidies by the Govt. agencies for wells, tub-ewells, machinery, farm equipment, horticulture etc.	5.09	37.44	46.57
(*E*) *Farm Machinery* (cumulative totals) :			
(i) Tube-wells ..	..	3,531	8,804
(ii) Tractors	458	1,625	3,950*

Data regarding the average yield and agricultural production have been obtained from the Statistical Abstracts of Punjab and others from the Pilot Project Officer, Ludhiana.

*Based on unofficial estimates.

In terms of rupees the gross agricultural income from major crops (maize, cotton, groundnut, wheat and gram) increased from 23.7 crores rupees in 1960-61 to 46.1 crores in 1965-66 and 65.5 crores in 1967-68. (Anonymous, 1968).

There is no doubt that Ludhiana was potentially the most promising district in the Punjab to start with and the achievements in agricultural production have further proven that the administrative machinery set-up did contribut

successful results. Considering the potentials, therefore, the other districts of Punjab may not be able to produce the same results within a similar period of time. Probably, production in Ludhiana can increase further, and other districts can come up to the comparable levels of production. It is also probable that in certain parts of other districts in the Punjab or the rest of the country, the potentialities may be even greater than those in Ludhiana district. The overall picture, therefore, appears to be a bright one. Before any high hopes are levelled for the country as a whole, it will be desirable to look deep into the probable factors that brought about increased production in this district.

The first and the foremost factor is the farmer himself. The Punjab farmer is ambitious socially and has a progressive out-look on life. He can take initiative and even take risks and has an insatiable inner desire to improve his lot. As a result of I.A.D.P. programme and the general green revolution brought about by the introduction of new high-yielding (dwarf) cereal varieties, the Punjab farmer has also established himself as an innovator. Whether maximum yield per hectare is the motive or total wealth by increasing the production of his farm as a whole is the ultimate aim, the farmer is willing to pay a high price for the wonder seeds. Some of the educated farmers have even started making their own selections of individual plants out of the seeds procured by them from innumerable sources.

A farmer might have all the qualities enumerated above yet either due to lack of proper education or opportunity in life he might not get the correct information on improved practices, on which he can build his faith. The wisdom in following the improved practices is, therefore, not merely to be conveyed to him but he has to be convinced of the positive results that can be achieved. All this is possible through the efforts of effective efficient and devoted Government or public agencies who would provide; visual demonstrations particularly in farmers' fields; news and broadcasts on the new or better discoveries; the verbal assurances of the Government or private agents on the expected profits by the adoption of new techniques; the required inputs, including irrigation facilities; required easy-to-obtain credits; assured marketing on incentive prices.

It is an accepted fact that Agricultural Colleges, Universities or other Institutions of higher learning have made their impact on the people everywhere. There are various visible and invisible ways by which the staff and the students bring about a silent revolution in the thinking and a general outlook of the farming community. These unnoticed and silent communications radiate from those institutions up to the very villages from where the staff and students keep coming and going to and fro. Apart from this, the new concepts of education adopted by the Punjab Agricultural University, in particular and other Agricultural Universities in general, have provided a regular extension education machinery through which a two-way contact is maintained between the scientists and the farmers in India. It is in the University that the staff of the State Departments of Agriculture gather to finalise package recommendations for various crops, for adoption by the farmers. There may not be any tangible proof as to the exact contribution of this University in bringing about the so-called green revolution in the Punjab State as a whole and I.A.D.P., Ludhiana District in particular but an Agricultural University like this, one must inevitably play the most significant role in the transformation of a tradition ridden rural community to a smiling, brimming and enlightened class of farmers who now can afford neat and clean clothes and can use tractors for transport to the various farm melas at the Campuses and the Farms of the University throughout the States of Punjab, Haryana and Himachal Pradesh. There is no reason why similar or even greater results cannot be achieved in other parts of the country, or for that matter, other food deficit areas of the world.

ACKNOWLEDGEMENT

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Indian Agriculture Tomorrow

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In the United States there have been remarkable developments during this twentieth century. Industrial expansion has been phenomenal. The rural population, those actually living on farms, has fallen from more than 20 per cent in 1900 to perhaps 5 per cent today. Agricultural production has increased greatly, both through additional acreage used for agricultural purposes, and because of greatly improved production per acre. Mechanization has cut the manpower needs on the farm to a fraction of what it was earlier. Excellent highways have been built and millions of automobiles and trucks have brought farm and market within brief travel time of each other. Farming is becoming more and more a business requiring a large investment, and less and less a way of life. Most farm children today attend consolidated schools that are just as large, just as well equipped and staffed as are city schools. Electricity, running water, sewage disposal systems, telephones, television—everything that the city dweller enjoys—are found in most rural homes today. None of these things were available in the rural areas in 1900.

A farmer who was a boy or a young man 60 years ago in the United States has had to make radical canges in the operation of his business during his lifetime. Without question the Land Grant College system, which integrated Teaching, Research and Extenion in the field of Agriculture, has been the most important factor in helping him to make the necessary adjustments.

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It was not a matter of planning ahead 50 years. No one had any idea that developments would take the course they did. But as conditions in the country changed, and forced changes in agriculture, or made them desirable, the research man and the rural economist suggested adjustments that should be made, and the extension agent carried the message to the farmer.

As the national economy developed, dominated by a burgeoning industrial sector, and as prices in general rose, the economics of agricultural production also changed. World Wars I and II resulted in suddenly increased requirements for food, and provided periods of high prices for farm products. In the early part of the century farm prices were low, and fertilizer relatively expensive. Little was used. Later, fertilizer costs remained about the same, but prices for farm products went up. More fertilizer could be used to advantage. The Agricultural Experiment Stations determined what applications would provide maximum profit and the extension agent immediately informed the farmer. This, and many other changes resulted in greater outlay for farm inputs, and gave rise to credit needs. This was another area where the Colleges gave a great deal of help. When markets were unsatisfactory, cooperatives were developed under the guidance of farm economists.

One of the most spectacular changes was the mechanization of farm operations. Many people thought the tractor could never replace the horse or mule. But as labour costs rose, and farm labour became almost unobtainable (especially in wartime), mechanization of all kinds expanded very rapidly. Better designed machinery, developed by Experiment Station or, more frequently, by farm machinery companies, was introduced. It worked, and it released still more rural people to go to the cities and take jobs in factories or go into business or the professions. The extension agricultural engineer has been and is today filling an important need. There has been constant change in the Extension Service to meet the evolving needs of the farmer.

Early in the programme the farmer did not trust the Extension Agent and had little faith in his recommendations. That picture changed, gradually at first and then more rapidly. Today the Agent is a valued consultant, and his office is

visited frequently.

The Research financed under the Land Grant system in the United States until very recently was restricted to solution of simple, everyday farm problems. It included, however, development of new varieties of crops, improvement of animal breeds, and some probing into theoretical areas, that had immediate possible application, such as utilization of hybrid vigour in plants and animals. The so-called "basic research" with no immediate practical objectives, may be carried on in the University, but is financed from other sources. It may appear to be a Land Grant function but it is not.

India today has entered on a period when there must be vast and probably radical change in her agriculture, and these changes will occur relatively rapidly. With increasing numbers of people living in cities and towns, and a smaller percentage actually operating farms, more food must be moved from farm to city. Transportation and storage facilities must be provided, and the distribution system developed. Credit facilities are needed not only to finance these activities, but to provide the cultivator with money to buy seed, fertilizer, feed, perhaps machinery, or to install a tube-well and irrigation system. These inputs are essential to the economical production of the increased output needed to meet the requirements of a growing population.

What will the changes be on Indian farms in the next half century ? We don't know any better than the American farmer in 1910 knew what course American agricultural production would take. Certainly the cost of farm labour is rising in Punjab, and industry is developing rapidly. Some mechanization is already becoming an economic necessity. Mechanization also speeds up land preparation and is almost a necessity for some crop sequences when two or even three crops are grown each year. But machinery reduces labour needs, and perhaps industry cannot take up all those who would be out of work. What adjustment will this require ?

Will the population continue to increase at a high rate ? If it does, our most optimistic forecasts suggest we could barely maintain the present substandard of nutrition through the rest of this century. The rate of population increase could well be a critical factor in determining the

course of changes in farming.

There are countless other factors the influence of which cannot be assessed accurately today. Indian agriculture must develop as these various factois become dominant and indicate the direction in which change must be made. Who is to advise and guide the cultivator in these vital matters ? There can be no better source than the Extension Service of the Agricultural University, backed by a research effort keyed to solving immediate problems as they arise. Apparently simple questions such as how much and what kind of fertilizer to use with a high yielding variety, or what changes in culture are required when dwaif wheats are grown, are vitally important. The right answers can *immediately* increase national food production. A study of amino-acid composition of proteins is probably of primary value as a guide to selection of foods for adequate nutrition. There is no immediate need for a better balanced protein from just one source. When increased production results in adequate food supplies from diverse sources, theie should be no difficulty in providing a balanced diet foi all.

If the Punjab Agricultural Univeisity will maintain the excellent relationship already established between Extenion and the cultivatoi, and if the Research units will willingly and rapidly adjust to the changing national scene, providing sound practical answers to rural problems, agricultural production will rise at the maximum possible rate. No one can say today what tomorrow's specific problems are going to be, but they can be recognized as they arise, and solved before they slow down food production. This is the task and the challenge. The experience at Punjab Agricultural University proves that the task can be accomplished and the challenge met. Multiplied through the programmes of sister institutions across the country it can produce for India the sound agricultural base upon which every successful nation has been built.

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ERRATA

Page No.	Printed as	To be read as
18	Jawahar Lal Nehru Krishi Vishvwidyla	Jawaharlal Nehru Krishi Vishwa Vidyalaya
20	some organisation	same organisation
21	*for universities*	*for other universities*
27	its views	their views
28	*in Seminar/Symposia :*	*in Seminars/Symposia :*
30	though administrative	though administratively
30	Auditors of the Examiners	Auditors or the Examiners
33	proportion/decision	*proportion according to decision*
33	Heades	Heads
34	in the routine	of the routine
36	*practical, along*	practical and theory, along
36	itellectualism	*intellectualism*
37	Radhakrishnana	Radhakrishnan
37	may home	my home
37	Goats	Goals
38	is a quite	*is a quote*
42	fertilizers were in	fertilizers were used in
42	towards their	towards the
51	*zinkin*	Zinkin
57	fit a gap	fill a gap
58	remaind	remind
64	critises	criticizes
67	"Yew I know"	"Yes I know"
67	Physist	*Physicist*
71	clearing	cleaning
73	cotouts	cutouts
73	*reader*	readers
74	low lost and case of	low cost and ease of
74	seeting	seating
78	will you	will help you
78	imortant	important
80	word	words
84	heterogenity	heterogeneity
89	entirity	entirely
90	Accounting Officer routine	Accounting, Office routine
94	Aggarwal J. C. 1916	Aggarwal, J. C. 1966
97	due, thus	are, thus
97	deisrable	desirable
97	cope	scope
97	devetailed	dovetailed
100	INTELLECTURAL	INTELLECTUAL
101	too many selection of aids	too many aids
103	back if	back of
105	three-diamensional	three-dimensional
109	team with	team work
109	*Bernald*	Bernard
109	student	students
110	REFERENCE	REFERENCES
111	Chakrabarti	Chakravarti
115	starts	stars
116	scandulous	scandalous
121	indispensible	indispensable
121	disciplines or biology	*discilpines of biology*
124	Philadephia	Philadelphia
124	Prentace	Prentice
132	and advisory	an advisory
133	the literate	the literature

Page No.	Printed as	To be read as
133	numberical	numerical
134	research's	researcher's
139	heridity	heredity
149	simpliest/simplext	simplest
169	unwidely	unwieldy
175	Varn No trand	Van Nostrand
178	developes	develops
178	changes introduces	changes introduced
179	profund and the	profound and the
179	Jawahar Lal Nehru Krishi Vidyala	Jawaharlal Nehru Krishi Vishwa Vidyalaya
186	medicind	medicine
187	ocourses	courses
206	plan materials	plant materials
206	surprize	surprise
209	the great teachers	that great teachers
209	spurpose	purpose
224	teacher completes with	teacher competes with
233	has not taken	has now taken
236	his decline	this decline
243	too pen	to open
244	and plants	of plants
244	provided	provide
245	cells	cell
249	place in the sum	place in the sun
249	and free from competition with other forms	delete
252	nitrogen-living	nitrogen-loving
252	on is own right	on its own right
253	original	origin
253	lavendor	lavender
255	a few months	a few mouths
257	latter	former
258	carnivous	carnivorous
258	lazards	lizards
261	a sexual	asexual
261	ostrick	ostrich
262	DZO	'Churu'
262	Sg. Jame's	St. Jame's
264	to the exhaustive	to be exhaustive
265	Leibntz	Leibnitz
267	Antony Var Leenwen Lock	Anton Van Leeuwen-hock
269	eparticle	particle
270	recon and mutton	recon and muton
271	phenomence	phenomena
271	delinated	delineated
274	nucleas	nucleus
278	prevading	pervading
284	Nucelic acid	Nucleic acid
285	molecules	molecule
295	somes where	somewhere
307	simplext	simplest
309	Osvals	Osvald
311	contended	contented
314	this areas	these areas
319	biologic	biological
323	amely	namely
327	to the end	towards the end
327	or it scientific	or scientific
335	*ood*	*Food*
336	the allies	the Allies
340	Vavilow	Vavilov
348	Kohlravi	Kohlrabi

Page No.	Printed as	To be read as
348	Many ther	Many other
350	*2nd=52*	*2n=52*
350	*O. satia* var *fatua*	*O. Sativa* var *fatua*
351	Chakravor	Chakravarti
351	7n=33	3n=33
352	*Hordeum vulgara*	*Hordeum vulgare*
358	1964	1694
358	imprve	improve
359	Since the	The
366	Precess	process
367	dulpication	duplication
370	pleiotrospic	pleiotropic
380	Discribminant	Discriminant
382	epistatis	epistasis
382	Kemthorne	Kempthorne
386	daw	doe
399	charactors	characters
397	as well-known	is well-known
398	old tons	old ones
399	read the mark	reach the mark
400	Henry Hoilt	Henry Holt
410	reproduced	reproduces
413	ond direct	and direct
414	prove	*proved*
419	magin	magic
424	evently	evenly
427	its associates	his associates
435	*heterogeniety*	heterogeneity
448	Dropping	Drooping
451	role of their	role of these
462	require	acquire
468	programme include :	programme which include :
470	raditionally	traditionally
471	uricentes	centuries
473	*Bacillus thuringensis*	*Bacillus thuringiensis*
473	advantage	advantages
474	constulted	consulted
475	inecticide	insecticide
476	Trails	*Trials*
477	side affects	side effects
477	delecterious	deleterious
477	chemosilants	chemosterilants
477	mandibulary glands	mandibular glands
480	Redueced	Reduced
481	resistence	resistance
481	more practical	more sceptical
485	*safty*	safety
489	osspores	oospores
495/97	fungistatis	fungistatic
497	controll	control
498	Eight the wheat rust	Fight the wheat rust
502	forest free	forest tree
504	stomates and hydathodes	stomata and hydathodes
508	microbex	microbes
509	IS has	It has
509	bilogical	biological
510	Mycelogy	Mycology
513	cellulotytic	*cellulolytic*
514	Inter-Astronantical	Inter-Astronautical
514	Fungi Imperfect	Fungi Imperfecti
514	Gr: wing	Growing
520	fires	*fibres*

Page No.	Printed as	To be read as
520	an other	and other
520	eaten vegetarian	eaten as vegetarian
520	soyabean	soybean
520	tonic	toning
531	Ratio if	Ratio of
534	chemotherapentic	chemotherapeutic
538	chenotherapy	chemotherapy
538	Izid	Ibid
540	ruptures bladder	ruptured bladder
542	Gardiac	Cardiac
542	pare	are
545	*River plate countries*	*River Plate Counties*
552	The spaying	The saying
552	Anothr	Another
553	Inda	India
559	Weight H.P. ratio	weight—H.P. ratio
576	context the it is	context that it is
577	speices	species
586	confining than	confining them
586	respectables	receptacles
595	Cone	Coyne
604	*Callosoburchus chinensis*	*Callosobruchus chinensis*
607	gelological	geological
609	drought-resistant	drought-resistance
610	out which	out of which
616	mountais	mountains
618	annual of rainfall	annual rainfall
621	scrubs	shrubs
623	intencified	*intensified*
625	Now here	Nowhere
626	interventing	intervening
630	walk swifty	walk swiftly
631	But he control	But the control
642	also in predominant	also the predominant
644	results of of a	results of a
645	reconditions	conditions
645	creates	create
661	farm produced	farm produce

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